

BMO TR-81-80

SAI DOCUMENT NO. SAI-79-506-VF

*2*  
**LEVEL III**  
*17108*  
*845*

**PERFORMANCE TECHNOLOGY PROGRAM  
(PTP-S II)**

**VOLUME III: APPENDIX**

INVISCID AERODYNAMIC PREDICTIONS FOR BALLISTIC REENTRY  
VEHICLES WITH ABLATED NOSETIPS

USER'S MANUAL

SCIENCE APPLICATIONS, INC.  
APPLIED MECHANICS OPERATION  
WAYNE, PENNSYLVANIA 19087

SEPTEMBER, 1979

FINAL REPORT FOR PERIOD MARCH 1978 - SEPTEMBER 1979

CONTRACT NO. F04701-77-C-0126

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AIR FORCE BALLISTIC MISSILE OFFICE  
NORTON AFB, CALIFORNIA 92409

**DTIC**  
**ELECTE**  
**S** **D**  
**DEC 28 1981**  
**D**

*472 106*  
**81 12 23 119**

AD A108846

DTIC FILE COPY

This final report was submitted by Science Applications, Inc., 1200 Prospect Street, La Jolla, California 92038, under Contract Number F04701-77-C-0126 with the Ballistic Missile Office, AFSC, Norton AFB, California. Major Kevin E. Yelmgren, BMO/SYDT, was the Project Officer in charge. This technical report has been reviewed and is approved for publication.

*Kevin E. Yelmgren*

KEVIN E. YELMGREN, Major, USAF  
Chief, Vehicle Technology Branch  
Reentry Technology Division  
Advanced Ballistic Reentry Systems


FOR THE COMMANDER

*Nicholas C. Belmonte*

NICHOLAS C. BELMONTE, Lt Col, USAF  
Director, Reentry Technology Division  
Advanced Ballistic Reentry Systems

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER BMO TR-81-80	2. GOVT ACCESSION NO. AD-A108846	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) "Performance Technology Program (PTP-S II), Vol. III, Inviscid Aerodynamic Predictions for Ballistic Re-entry Vehicles with Ablated Nosetips. Appendix: User's Manual."		5. TYPE OF REPORT & PERIOD COVERED Final Report: 3/78 to 9/79
7. AUTHOR(s) Darryl W. Hall Catherine M. Dougherty		6. PERFORMING ORG. REPORT NUMBER SAI-79-506-VF-VOL-3-111
9. PERFORMING ORGANIZATION NAME AND ADDRESS Science Applications, Inc. Applied Mechanics Operation Valley Forge, Pennsylvania		8. CONTRACT OR GRANT NUMBER(s) F04701-77-C-0126
11. CONTROLLING OFFICE NAME AND ADDRESS Ballistic Missile Office Norton AFB, California		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Tasks 3.2.1.2, 3.2.1.3
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE September 1979
		13. NUMBER OF PAGES 116
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Flow Field Blunt Body Code Reentry Vehicle Asymmetric Nosedtips Conformal Mapping		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report documents the use of the CM3DT inviscid blunt body flow field code. Details are provided on the organization of the code and the inputs required for its operation. Code inputs and outputs are explained for several sample cases, and glossaries of input variables, output variables, and subroutines are provided. The coupling of the CM3DT to a steady supersonic afterbody code is described. 		

# TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT (DD1473)	1
TABLE OF CONTENTS	1
LIST OF FIGURES	2
SECTION 1 INTRODUCTION	3
SECTION 2 DESCRIPTION OF THE TECHNIQUE	4
SECTION 3 LOGICAL ORGANIZATION OF THE CODE	6
SECTION 4 CODE INPUTS	9
4.1 GEOMETRY	9
4.2 FREESTREAM CONDITIONS AND THERMODYNAMICS	21
4.3 GRID DEFINITION	24
4.4 OUTPUT CONTROLS	29
4.5 OTHER PROGRAM CONTROLS	30
SECTION 5 CODE OUTPUT	33
5.1 PRELIMINARY OUTPUT	33
5.2 STANDARD OUTPUT	35
5.3 OPTIONAL OUTPUT	36
SECTION 6 COUPLING OF NOSETIP CODE TO SUPERSONIC AFTERBODY CODE	38
SECTION 7 INPUT GUIDE LIST AND SAMPLE CASES	47
7.1 INPUT GUIDE (CM3DT)	47
7.2 INPUT GUIDE (AFTERBCDY CODE)	50
7.3 SAMPLE CASES	51
SECTION 8 DEFINITION OF APPLICABILITY OF CM3DT NOSETIP CODE	56
SECTION 9 REFERENCES	63
SECTION 10 APPENDICES	64
10.1 GLOSSARY OF INPUT VARIABLES	64
10.2 GLOSSARY OF OUTPUT VARIABLES	71
10.3 GLOSSARY OF SUBROUTINE NAMES	75
10.4 SUMMARY OF COORDINATE TRANSFORMATIONS	78
10.5 SAMPLE CM3DT OUTPUT	85

# LIST OF FIGURES

	<u>Page</u>
4.1 ORIENTATION OF NOSETIP GEOMETRIC CENTERLINE	10
4.2 DEFINITION OF DOWNSTREAM BOUNDARY	12
4.3 ARBITRARY GEOMETRY OPTIONS (NPHI>0)	15
4.4 ARBITRARY GEOMETRY OPTIONS (NPHI<0)	18
4.5 CENTERLINE OFFSET DEFINITION (NPHI<0)	19
4.6 CM3DT SIGN CONVENTIONS	23
4.7 HINGE POINT LOCATIONS IN $\phi = \phi_L$ PLANE	26
4.8 $(\xi, \eta)$ COORDINATE GRID	28
6.1 AFTERBODY CARTESIAN COORDINATE SYSTEM	42
6.3 FORCE AND MOMENT SIGN CONVENTIONS	43
7.1 MIB CONFIGURATION	52
7.2 BLUNT-1 CONFIGURATION	54
8.1 GENERALIZED INDENTED NOSETIP GEOMETRY	58
8.2 LIMITS OF APPLICABILITY OF THE CM3DT CODE TO INDENTED SHAPES	61
10.1 AFTERBODY COORDINATE SYSTEM	79
10.2 NOSETIP GEOMETRIC COORDINATE SYSTEM ORIENTATION	81
10.3 NOSETIP COMPUTATIONAL COORDINATE SYSTEM ORIENTATION	83

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

**DTIC**  
**ELECTE**  
**S** **D**  
**DEC 28 1981**  
**D**

## SECTION 1

### INTRODUCTION

This report is a comprehensive user's guide to the CM3DT blunt body code for the calculation of inviscid, hypersonic flow over ablated reentry vehicle nosetips. This code provides numerical solutions to the exact inviscid time-dependent fluid mechanic equations and is formulated in terms of a generalized coordinate system that is automatically aligned with asymmetric nosetip geometries. The analysis from which this code has been developed may be found in Reference 1.

A brief description of the techniques used in this code is given in Section 2.0, and the logical organization of the code is described in Section 3.0. The inputs required by this code are defined in Section 4.0, and Section 5.0 describes the output generated.

The coupling of this nosetip flow field code to an inviscid supersonic aftertody code, enabling inviscid aerodynamic predictions to be made for entire reentry vehicles, is described in Section 6.0. Samples of the code inputs are provided in Section 7.0. Section 8.0 presents criteria to define those indented nosetip shapes for which the CM3DT code can be expected to produce accurate inviscid flow field results.

The CM3DT code was developed on the CDC Cyber 176 computer, and is compatible with the CDC 7600 computer. Qualified users may obtain this program through BMO/SYDT.

## SECTION 2

### DESCRIPTION OF THE TECHNIQUE

The CM3DT code is a numerical procedure for the calculation of hypersonic inviscid flows over reentry vehicle nosetips. This procedure has been developed with the goal of computing flows over ablated, asymmetric nosetip geometries which could not be treated by previous inviscid blunt body codes. In particular, this technique has extended the range of nosetip geometries for which successful inviscid flow field calculations can be performed by using a new coordinate system which can be closely aligned with the body geometry and by using the  $\lambda$ -differencing scheme for calculations on indented shapes where embedded shocks form.

The CM3DT code computes the steady flow over a nosetip as the asymptotic limit of an unsteady flow, integrating the inviscid time-dependent equations with a second-order accurate, forward-marching (in time), explicit finite difference scheme. Body and bow shock points are computed using forms of the appropriate characteristic compatibility conditions. Because of the inviscid flow assumption, this technique is limited to high Reynolds number flows (thin boundary layers) without separation.

The coordinate system used in this technique is the result of conformal transformations carried out in each meridional plane, closely aligning one of the coordinates with the body, and having another coordinate nearly normal to the body. The conformal transformations are defined in terms of "hinge points", which are discrete points selected within each meridional plane that approximate the body meridional curve. The hinge points may be specified by the user of the technique, or can be generated internally by the code.

Numerical calculations are performed in a computational coordinate system, in which mesh points are equally spaced in the transformed coordinate system: circumferentially, along the body profile, and between the body and the shock.

Two computational procedures are available within the CM3DT code; the basic non-conservation approach and the  $\lambda$ -differencing approach. The non-conservation procedure is the standard technique for most convex nosetip flow field calculations; however, for calculations where embedded shocks form, the  $\lambda$ -differencing technique must be used. The  $\lambda$ -differencing technique is capable of computing embedded shocks in an approximate manner by use of a finite difference technique that accurately models the physical domain of dependence of each point being computed.

The CM3DT blunt body code has been coupled to a steady supersonic afterbody code to enable the prediction of inviscid aerodynamic characteristics for an entire reentry vehicle with an ablated nosetip. For a maximum flexibility, the nosetip centerline may be rotated in both pitch and yaw relative to the afterbody axis, which may itself be bent in the pitch plane.

For a typical blunt body calculation, with 6 points between the body and bow shock, 18 points along the body, and 9 circumferential planes, and run for 400 time steps, the non-conservation code requires approximately two minutes central processor time on the CDC Cyber 176 computer, while the  $\lambda$ -differencing procedure requires approximately three minutes. (In comparison, the blunt body code formulated in a spherical coordinate system described in References 2 and 3 requires slightly more than one and a half minutes for the same case.) The CM3DT code requires 81000 words of core storage.

The analysis on which the CM3DT code is based is described in more detail in Reference 1.



## SECTION 3

### LOGICAL ORGANIZATION OF THE CODE

This section contains a description of the logical flow of the CM3DT program. An alphabetical listing of the subroutines found in CM3DT, together with a brief description of each routine, may be found in the Appendix, Section 10.3.

The main program (CM3DT) reads and prints out the input data. Freestream and stagnation point conditions are calculated (FREE, ATMP, STAGPT). For a real gas calculation, tables of shock properties are computed (SHKTAB). Hinge point locations are calculated, if not input, and printed out (HING3D). The required geometric parameters are determined using GEOM3 (analytic geometry), GEOM4 (arbitrary geometry with no centerline offset), or GEOM5 (arbitrary geometry with centerline offset). An approximate bow shock shape is defined, the computational grid is determined, and coordinate transformation parameters are calculated for each grid point (GRID3D, MAP3D). Initial estimates of pressure, entropy and the transformed velocity components are made at each point in the computational grid. If the option to save data on a binary file has been chosen, the binary file is initialized and the data written (BFL3CM). (In the case of a restart, all initial data are read from the binary file.)

The difference equations for the flow variables of pressure, velocity components, and entropy are solved in PVE3DNC if the non-conservation form has been chosen, or in PVE3DL if the  $\lambda$ -scheme is desired. At the beginning of each of these subroutines, the time step counter is incremented by one. When the predictor-corrector loop for a time step has been completed, data at each grid point are printed if output is desired at that step, and saved on the binary file if at a step

specified. If the current time step is not the last step desired, a transfer back to the beginning of PVE3DNC or PVE3DL is made; otherwise, control returns to CM3DT, and the program terminates.

The CM3DT program requires 81000 (decimal) words of memory for execution, without overlays. The program may be compiled and executed from an UPDATE program library or loaded and executed from a user-created LIBRARY. In the first case, it is necessary to omit from the list of subroutines to be compiled either PVE3DNC (if the  $\lambda$ -scheme option is chosen), or PVE3DL (if the non-conservation method is desired). Since these subroutines are mutually exclusive, loading both would unnecessarily increase the core storage required. In like manner, loading from a LIBRARY requires use of the LDSET(OMIT=PVE3DNC) or LDSET(OMIT=PVE3DL) command in the CDC control card stream. Regardless of the method of loading the program, it is necessary to preset core memory to zero before initiating execution. Following are examples of each of the above methods of loading and executing CM3DT:

1.) Compiling and executing CM3DT from an UPDATE program library:

```

JOB CARD,
ACCOUNT,
REQUEST, TAPE21, *PF.
ATTACH, OLDPL, CM3DTPL, ID=-----
UPDATE.
FTN(I=COMPILE, B=CM3DTB, L=0)
LDSET(PRESET=ZERO)
CM3DTB.
CATALOG, TAPE21, CM3DTDATA, RP=999, ID=-----
7/8/9
*COMPILE CM3DT, PVE3DNC, HING3D, GRID3D, OUT3D, BFL3CM, MAP3D
*COMPILE GEOM3, GEOM4, GEOM5, STAGPT, SHKTAB, SHOCK, FREE, RGAS, ATMP
*COMPILE CUFT1, CUFT2, TBL1, ATERR, IDEAL, LINE, FLERR, TBL, TLU1
7/8/9
      CM3DT      INPUT DATA
6/7/8/9

```

2.) Loading and executing CM3DT from a user library:

```
JOB CARD.  
ACCOUNT.  
ATTACH LIB, CM3DTLIB, ID=.....  
LIBRARY (LIB)  
LDSET (PRESET=ZERO, OMIT=PVE3DNC)  
LIBLOAD (LIB, CM3DT)  
EXECUTE.  
7/3/9  
CM3DT INPUT DATA  
6/7/8/9
```

The file specified for storage of binary information in the CM3DT program is TAPE21. Since TAPE21 is both an input and an output device to the CM3DT program, it is advisable, in cases of restart, for the user to attach the data file from which the program is to be restarted, with some designator other than TAPE21, and then copy this file to a TAPE21 local to the job, to eliminate loss of data in the event of error.

In coupling the CM3DT program to the afterbody code, it is first necessary to perform the CM3DT calculation and save the data. Then the afterbody program must be modified in the following manner:

- 1.) Subroutines CM3ST, REALP, and BFL3CM must be incorporated into the afterbody code,
- 2.) The variables X0, Z0, ZB and TEST(4) must be added to the list of input variables, with the default values of the first three set at 0.0 and the fourth at 1.0E-3.

## SECTION 4

### CODE INPUTS

This section details the input variables required by the CM3DT code. The input variables are discussed in their natural groupings; i.e., geometry specification, freestream conditions, grid selection, output controls, and special options. A glossary of all input variables is provided in the Appendix, Section 10.1.

#### 4.1 GEOMETRY

The body geometry can be specified in either of two ways: analytically (for axisymmetric geometries) or by tabulation of body points (for arbitrary geometries). Several options are available within the arbitrary geometry definition procedure to simplify the input required for special cases; these options are detailed in Section 4.1.2.

Several geometric input parameters are common to both the analytic and arbitrary geometric definition procedures. In both cases the geometry is defined relative to a user defined nosetip geometric axis, which must intersect the afterbody axis. For generality, the afterbody axis may be bent in the pitch plane, and the nosetip geometric axis may be rotated in both pitch and yaw from the bent afterbody axis.

The orientation of the nosetip geometric axis relative to the afterbody axis is illustrated in Figure 4.1. The bend angle (if any) of the afterbody axis in the pitch plane is denoted by  $\delta_A$  (DELA), input in degrees. The angles  $\delta_1$  (DEL1) and  $\delta_2$  (DEL2), also specified in degrees, define the orientation of the nosetip geometric axis relative to the bent afterbody axis in the pitch and yaw planes, respectively. This procedure for the definition of the nosetip geometric axis ( $\hat{x}$ -axis) allows the user

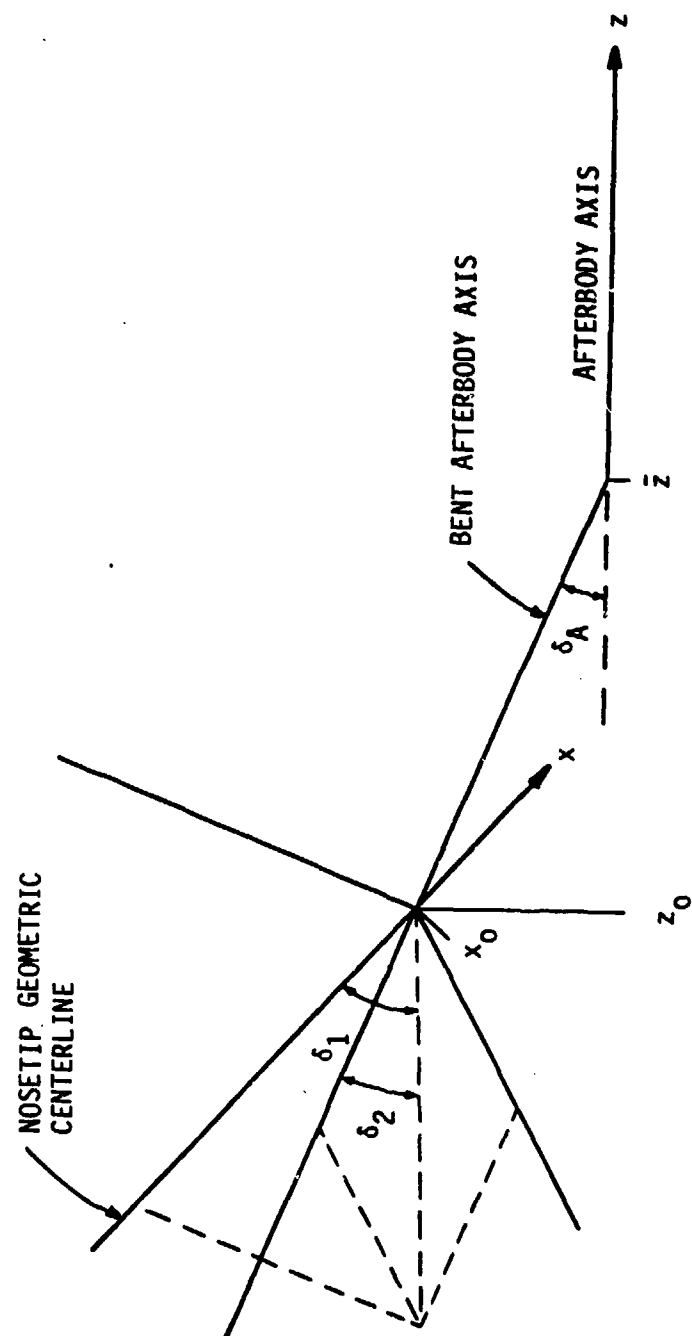


FIGURE 4.1. ORIENTATION OF NOSETIP GEOMETRIC CENTERLINE

the flexibility of using the most appropriate axis for defining an ablated nosetip geometry, independent of the orientation of the nosetip shape relative to the afterbody. The geometric nosetip axis intersects the bent afterbody axis at  $\hat{x} = \hat{x}_0(XH0)$ .

Two other geometric parameters must be specified in all cases. The first, XBO, is the point on the  $\hat{x}$ -axis that intersects the body surface, as shown in Figure 4.2. The second parameter, the array XBB(L), specifies the  $\hat{x}$  locations at the body that define the downstream boundary of the region to be computed, as illustrated in Figure 4.2. Details on the use of the XBB array vary with the geometry option used, and are discussed in Sections 4.1.1 and 4.1.2.

In all cases, the values in the XBB array must be selected sufficiently far downstream that the flow across the downstream boundary is supersonic. Additionally, the region of influence of any downstream boundary point must not contain any other. The downstream boundary must be selected so that the region computed will include complete shock layer information in the initial plane for the afterbody calculation.

#### 4.1.1 Analytic Geometry

Sufficiently regular, axisymmetric geometries may be defined analytically in CM3DT. The analytic description consists of specification of coefficients of a general equation for each of several curve segments. With this geometry option, the nosetip geometric coordinate system  $(\hat{x}, \hat{y}, \hat{\phi})$  serves as the computational coordinate system  $(x, y, \phi)$ . The number of segments to be used is specified by NSEG; a maximum of six segments is allowed. Endpoints of the segments are defined in the ADIV(J) array; NSEG-1 values of ADIV must be input. Within each segment, the curve is defined from

$$y(x) = A_1 + A_2\bar{x} + A_3\bar{x}^2 + A_4\bar{x}^3 + A_5\bar{x}^4 + A_6\bar{x}^5 + A_7\bar{x}^{A_8} + A_9 \sqrt{A_{10}^2 - (\bar{x} - A_{11})^2} \quad (4.1)$$

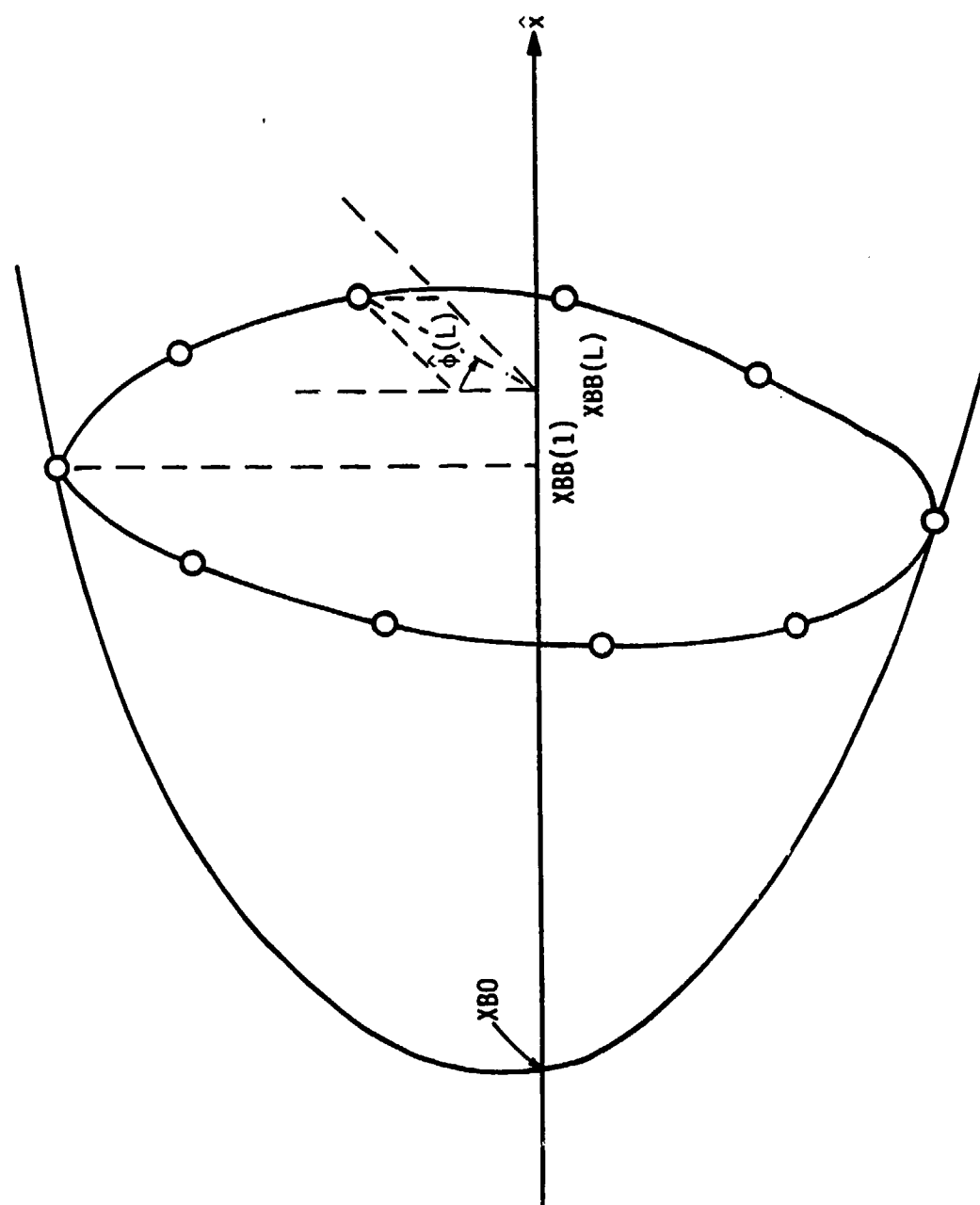


FIGURE 4.2. DEFINITION OF DOWNSTREAM BOUNDARY

where  $\bar{x} = \hat{x} - A_{12}$ . The coefficients  $A_j$  for each segment  $j$  are input via the ACOF(I,J) array.

When using the analytic geometry option, the user must ensure that the analytic description is consistent with the value of X30 specified, and that the segments specified are continuous.

To define the downstream boundary of the computation region when using this geometry option, only XBB(1) need be input, as the downstream boundary is assumed to be axisymmetric for axisymmetric nosetip geometries.

#### 4.1.2 Arbitrary Geometry

Two arbitrary geometry options are available within the CM3DT code. In both cases, the nosetip geometry is defined in the  $(\hat{x}, \hat{y}, \hat{\phi})$  cylindrical coordinate system, which intersects the bent afterbody axis at  $\hat{x} = \hat{x}_0$  (XHO) and is oriented relative to the bent afterbody axis by the angles  $\delta_1$  (DEL1) and  $\delta_2$  (DEL2). The first arbitrary geometry option allows definition of profiles in meridional planes to establish the nosetip geometry (with several special options available for defining the nature of the cross-sections). The second option allows the specification of cross-sections (of several special types) at specified axial stations, with the cross-section centers potentially offset from the  $\hat{x}$  axis. These options are described in greater detail below.

##### 4.1.2.1 Arbitrary Geometry Without Centerline Offsets (NPHI>0)

With this option, arbitrary geometries are defined by tabular specification of points XB(I,L), YB(I,L) in the  $\hat{\phi}$  planes defined by the array PHIBD(L) (degrees). NPHI (which is a positive number for this option) specifies the number of PHIBD planes in which XB, YB points are to be defined, and the array NPTS(L) specifies the number of XB, YB points input in each plane. A maximum of nine planes of geometry may be defined, and a maximum of 50 XB, YB points may be specified in each plane.



When this arbitrary geometry option is used, the computational  $(x,y,\phi)$  coordinate system is identical to the nosetip geometry  $(\hat{x},\hat{y},\hat{\phi})$  coordinate system. The program automatically sets  $XB(1,L)$  to  $XB0$  and  $YB(1,L)$  to 0.

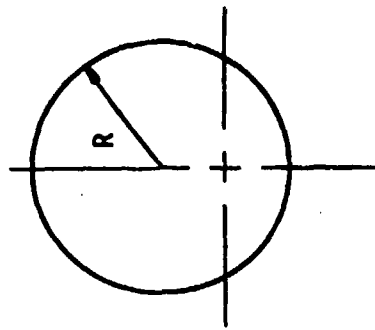
Cubic spline fits of the  $XB,YB$  data are used both longitudinally and circumferentially to determine the body geometry at any point. A number of options are available with the arbitrary geometry procedure to provide for special cases in which the cross-sectional character of the nosetip is known. These cases are enumerated below, and are illustrated in Figure 4.3. Use of these special cases is determined by the value of  $NPHI$  specified.

#### Axisymmetric Arbitrary Geometry ( $NPHI = 1$ )

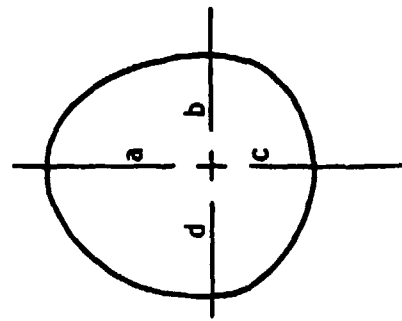
This option is exercised by setting  $NPHI = 1$ . Circular cross-sections are assumed, and only one  $XB,YB$  table need be input, along with  $NPTS(1)$ . The  $PHIBD$  array is not required for this case.

#### Offset Circular Cross-Sections ( $NPHI = 2$ )

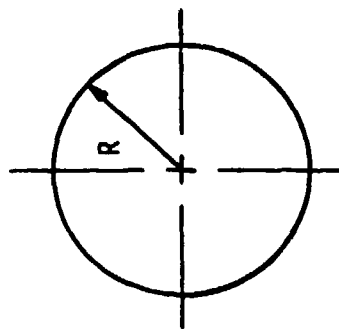
With this option, the body cross-sections are assumed to be circular, with the centers of the cross-sections offset from the nosetip computational axis in the pitch plane. Use of this option requires setting  $NPHI = 2$  and supplying two sets of  $XB,YB$  data, with the appropriate values of  $NPTS$ . The  $PHIBD$  array is automatically set to  $0^\circ$ ,  $180^\circ$ , and no  $PHIBD$  input is required of the user. The arrays  $XB(I,1)$  and  $YB(I,1)$  are assumed to define points in the  $\hat{\phi} = 0^\circ$  plane, and the  $XB(I,2)$  and  $YB(I,2)$  arrays are assumed to define points in the  $\hat{\phi} = 180^\circ$  plane, relative to the nosetip geometric coordinate system.



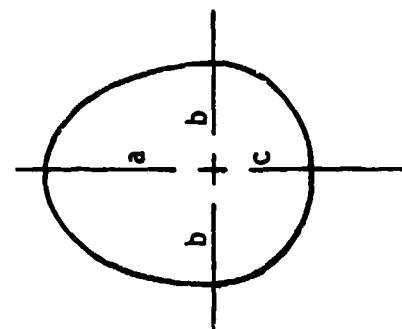
OFFSET CIRCULAR  
CROSS-SECTIONS  
NPHI = 2



QUAD-ELLIPTIC CROSS-SECTIONS  
NPHI = 4 (ISA = 2)



CIRCULAR CROSS-SECTIONS  
(AXISYMMETRIC)  
NPHI = 1



BI-ELLIPTIC CROSS-SECTIONS  
(PITCH PLANE OF SYMMETRY)  
NPHI = 3

FIGURE 4.3 ARBITRARY GEOMETRY OPTIONS (NPHI>0)

### Bi-Elliptic Cross-Sections (NPHI = 3)

By setting NPHI = 3, bi-elliptic cross-sections are assumed, and the body geometry is assumed to be symmetric about the pitch plane. Three planes of XB,YB data with their associated values of NPTS are required and are assumed to apply to the  $\phi = 0^\circ$ ,  $90^\circ$ , and  $180^\circ$  planes. With this option, each quadrant of the cross-section is fit as the quadrant of an ellipse. Again, the PHIBD array is not required for this option.

### Quad-Elliptic Cross-Sections (NPHI = 4 and ISA = 2)

The quad-elliptic cross-section option is exercised by setting NPHI = 4 with ISA = 2 (no pitch plane of symmetry). With this option, XB,YB and NPTS data must be input in the  $\phi = 0^\circ$ ,  $90^\circ$ ,  $180^\circ$ , and  $270^\circ$  planes and no PHIBD input is required. Each quadrant of the cross-section is assumed to be the quadrant of an ellipse. (Note that when NPHI = 4 and ISA = 1, arbitrary cross-sections with a pitch plane of symmetry are assumed.)

When using this arbitrary geometry option (NPHI>0), the downstream boundary of the computational region is defined by specifying the array XBB(L), where each element defines the location of the downstream boundary at the body in the corresponding PHIBD(L) plane of input geometry. The appropriate values of XBB in the planes to be computed are determined automatically within CM3DT by linear interpolation in  $\phi$ .

#### 4.1.2.2 Arbitrary Geometry with Centerline Offsets (NPHI<0)

In using this arbitrary geometry option, body cross-sections of certain limited classes are defined in specified planes normal to the nosetip geometric axis,  $\hat{x}$ . The center of each cross-section may, however, be offset in both the pitch and yaw planes from the  $\hat{x}$  axis.\*

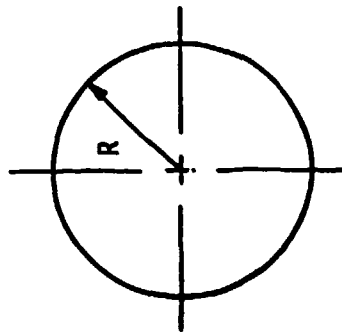
This geometry option is invoked by specifying a value of NPHI<0; the value of NPHI determines the type of cross-section to be defined, as shown in Figure 4.4. Admissible cross-sections include circular, elliptic, bi-elliptic, and quad-elliptic.

Stations at which the cross-sections are to be defined are specified through the array XE(I), where XE represents  $\hat{x}$ , the axial coordinate in the nosetip geometric coordinate system (which is related to the bent afterbody axis through the values input for DEL1, DEL2, and XH0). Cross-sections may be defined at up to 50 stations, and XE(1) must equal XB0. The number of cross-sections input is set by NPTS(1).

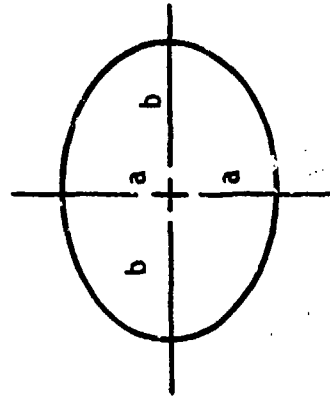
At each of the specified stations, the offset of the cross-section center from the geometric axis is defined by the arrays D1(I) (offset in pitch plane) and D2(I) (offset in yaw plane), as shown in Figure 4.5. An option also exists in which the centerline offset in the pitch plane may be defined analytically through the ACOF and ADIV arrays, using the same approach as for the analytic description of axisymmetric body geometries, except that the number of segments used is input as a negative number (NSEG<0). With the pitch offset defined analytically, the yaw offset is assumed to be 0.

Parameters describing each cross-section are input through the arrays AE(I), BE(I), CE(I), and DE(I), which correspond to the quantities a, b, c, and d shown in Figure 4.4. The types of cross-sections allowed are detailed below.

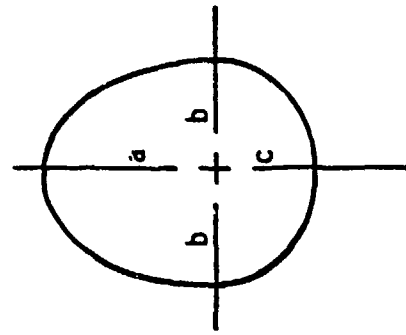
-----  
\*Note that if  $\delta_1 \neq 0$ ,  $\delta_2 \neq 0$ , or  $\delta_A \neq 0$ , the nosetip cross-sections will not be parallel to afterbody cross-sections. It is the responsibility of the user to ensure compatibility between the nosetip and afterbody geometry definitions.



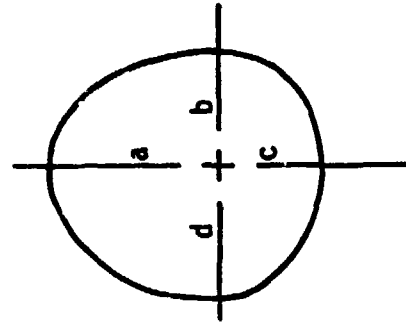
CIRCULAR CROSS-SECTIONS  
NPHI = -1



ELLIPTIC CROSS-SECTIONS  
NPHI = -2



BI-ELLIPTIC CROSS-SECTIONS  
NPHI = -3



QUAD-ELLIPTIC CROSS-SECTIONS  
NPHI = -4

FIGURE 4.4. ARBITRARY GEOMETRY OPTIONS (NPHI < 0)

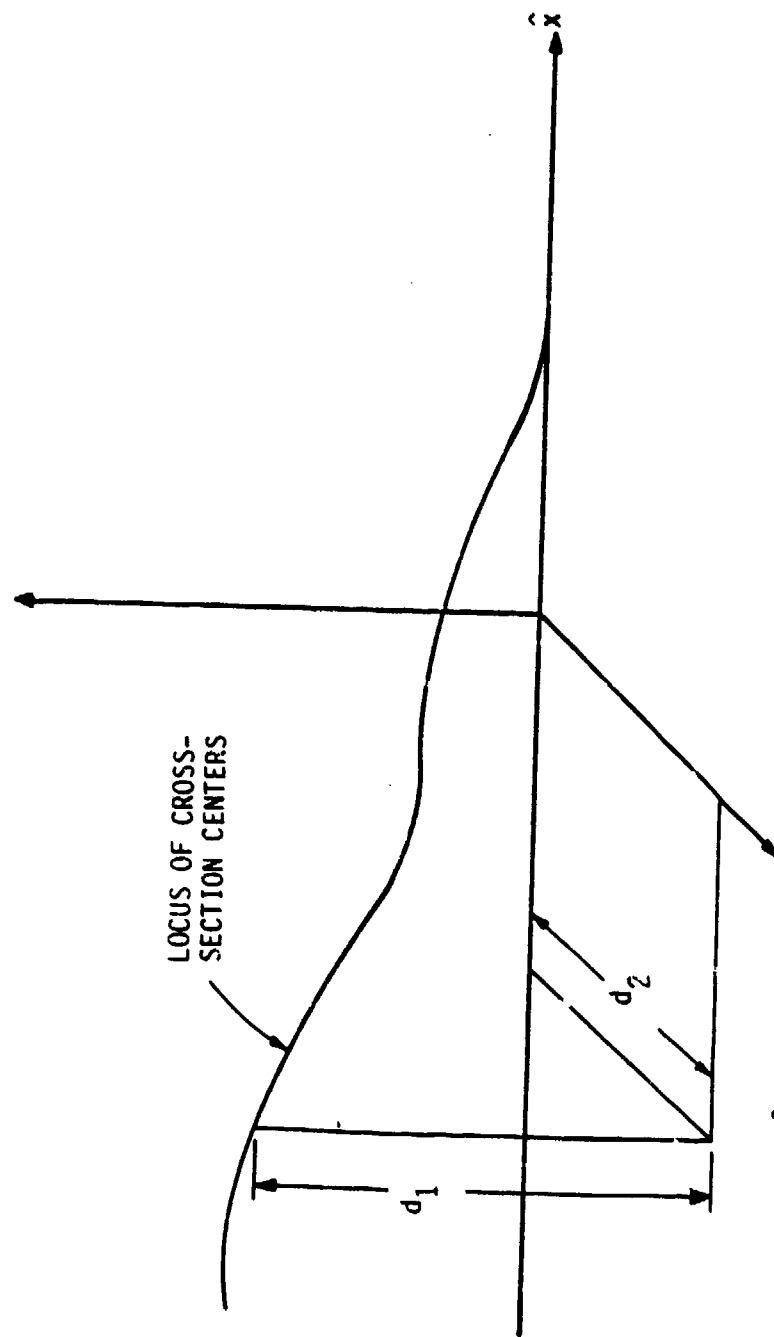


FIGURE 4.5. CENTERLINE OFFSET DEFINITION ( $NPHI < 0$ )

#### Circular Cross-Sections (NPHI = -1)

This option is exercised by setting NPHI = -1. Circular cross-sections are assumed, and input is required for the XE and AE arrays only, as well as the definition of the offset of each cross-section center.

#### Elliptic Cross-Sections (NPHI = -2)

By setting NPHI = -2, elliptic cross-sections are assumed, with input required for the XE, AE, and BE arrays, plus definition of the offset of the cross-section centers.

#### Bi-Elliptic Cross-Sections (NPHI = -3)

With this option, the body cross-sections are assumed to be bi-elliptic. Use of this option requires setting NPHI = -3 and supplying values for the arrays XE, AE, BE, and CE, as well as the information required to define the offset of the cross-section centers.

#### Quad-Elliptic Cross-Sections (NPHI = -4)

The quad-elliptic cross-section option is exercised by setting NPHI = -4 and supplying data for the XE, AE, BE, CE, and DE arrays, as well as the definition of the offset of each cross-section center.

When this arbitrary geometry option is used, it is necessary to define a computational  $(x, y, \phi)$  coordinate system that differs from the geometric  $(\hat{x}, \hat{y}, \hat{\phi})$  system to avoid multi-valued body geometric functions  $y = y_b(x, \phi)$ . The computational x-axis is defined automatically within CM3DT as a straight line that passes through the most forward point of the body, specified by  $XE(1) = XB0$ ,  $D1(1)$ , and  $D2(1)$ , and that intersects the  $\hat{x}$  axis at  $\hat{x}_0$  (XHO). (Note that the input XHO in CM3DT is identical

to the input XO in the afterbody code, described in Section 7.2.) Details of the coordinate transformations are provided in the Appendix, Section 10.4.

Calculations required for the computational centerline are carried out internally within CM3DT, including redefinition of XBO and XHO for consistency with the new coordinate system, with XBO set equal to zero at the geometric stagnation point. In addition, new values of  $\delta_1$  and  $\delta_2$  are computed to define the orientation of the new computational axis relative to the bent afterbody axis. New values of  $\alpha$  and  $\beta$  (relative to the computational axis) are also computed from the new values of  $\delta_1$  and  $\delta_2$ , as discussed in Section 6.

When using this geometry option, the downstream boundary of the computational region is defined by specifying XBB(1); the downstream boundary is then taken to be the axial location XE(I) that is the first one located downstream of XBB(1). This boundary in the  $\hat{x}$ -system is then transformed internally within the CM3DT code to produce a new array of XBB data for the planes to be computed in the computational (x,y, $\phi$ ) coordinate system.

## 4.2 FREESTREAM CONDITIONS AND THERMODYNAMICS

### 4.2.1 Freestream Conditions

For each calculation it is necessary to specify the freestream Mach number (AMINF) or the freestream velocity (QINF), as well as the static pressure and temperature (PINF and TINF). Values of PINF and TINF will be generated automatically from the 1962 standard atmosphere tables by specifying the desired altitude (ALT) and the flag IATMP  $\neq$  0. For non-dimensional ideal gas calculations, PINF and TINF are set to 1.0 (default values).



The orientation of the vehicle relative to the freestream velocity vector is defined by specification of the angle of attack (ALPHA) and the sideslip angle (BETA). The angles ALPHA and BETA, specified in degrees, are defined relative to the unbent afterbody axis; the CM3DT code will automatically compute the values of  $\alpha$  and  $\beta$  relative to the nose-tip computational axis as required for the computational procedure. Thus the orientation of the nosetip centerline relative to the wind vector is defined in terms of ALPHA, BETA, DELA, DEL1, and DEL2. (Note that if  $NPHI < 0$ , the values of DEL1 and DEL2 are recomputed internally by CM3DT.)

When  $ISA = 1$  is input, signifying a pitch plane of symmetry, the sideslip angle BETA is automatically set to zero by the code.

Sign conventions for ALPHA and BETA are shown in Figure 4.6; positive ALPHA implies nose up and positive BETA implies nose left, relative to the freestream velocity vector.

#### 4.2.2 Thermodynamics

Two options are available within the CM3DT code for the thermodynamic model used: ideal gas and equilibrium air (real gas). These options are described in more detail below.

##### 4.2.2.1 Ideal Gas (IRG = 0)

The standard operating procedure for ideal gas calculations is to use non-dimensional variables, in which  $PINF = TINF = RIDEAL = 1$ . With this normalization the variables take the forms:

<u>CM3DT</u>	<u>ACTUAL</u>
$p$	$p/p_{\infty}$
$\rho$	$\rho/\rho_{\infty}$
$T$	$T/T_{\infty}$
$(u,v,w)$	$(u,v,w)/\sqrt{p_{\infty}/\rho_{\infty}}$

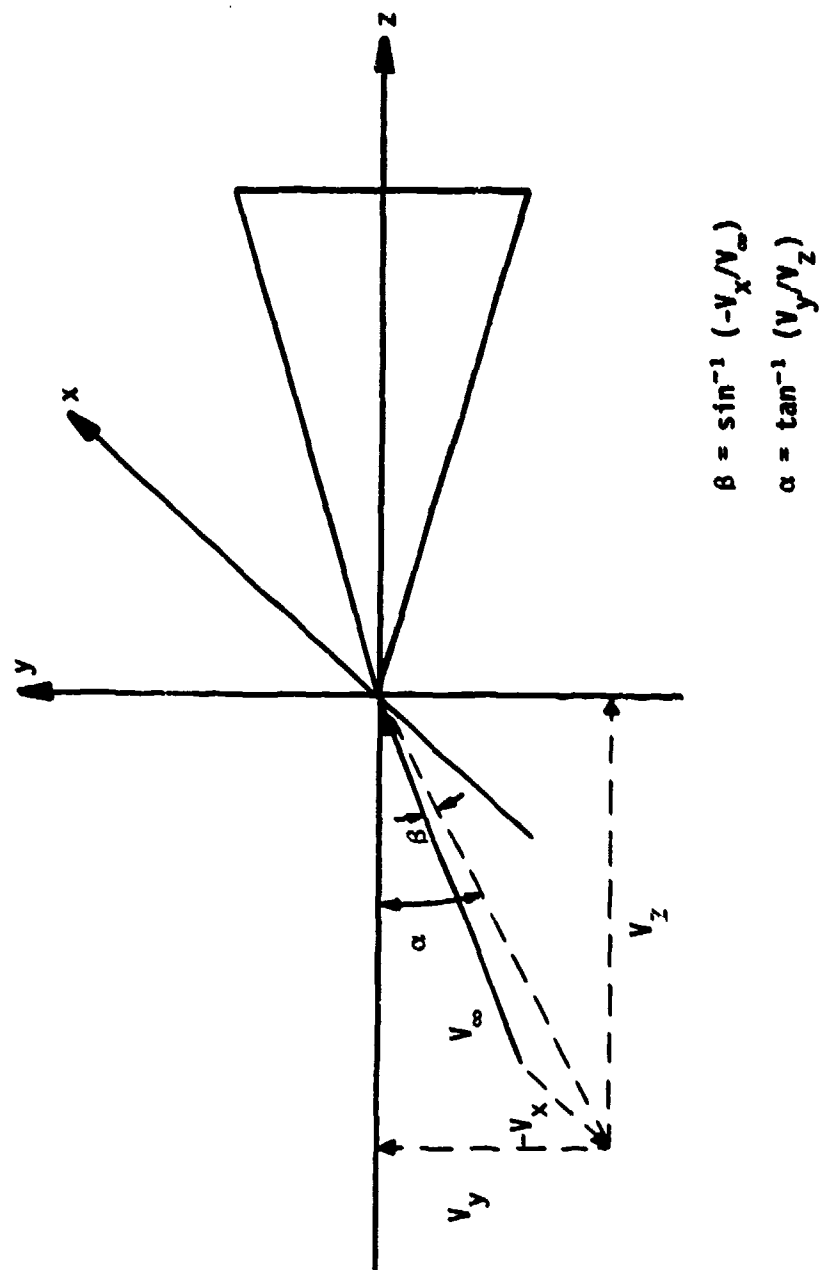


FIGURE 4.6. CM3DT SIGN CONVENTIONS

Note that with this formulation the gas law becomes  $p = \rho T$ . The isentropic exponent is specified as GIDEAL. If desired, a compressibility factor (ZIDEAL) may also be specified.

Dimensional ideal gas calculations are also possible, requiring only that a dimensionally consistent value of RIDEAL is specified, as well as appropriate values of PINF and TINF.

#### 4.2.2.2 Real Gas (IRG = 1)

All quantities in real gas calculations are dimensional with the units:

<u>CM3DT</u>	<u>ACTUAL</u>
p	lbf/ft <sup>2</sup>
$\rho$	slugs/ft <sup>3</sup>
T	°R
(u,v,w)	ft/sec

The real gas thermodynamic properties available in CM3DT are for equilibrium air. Gas properties required during the calculation are obtained by interpolation on the thermodynamic property tables supplied with the code.

### 4.3 GRID DEFINITION

In the CM3DT code a conformal transformation is used to map the cylindrical  $(x,y,\phi)$  computational space onto  $(\xi,\eta,\theta)$  space, where  $\eta = \text{constant}$  surfaces are closely aligned with the body surface and  $\xi = \text{constant}$  surfaces are nearly normal to the surface. The transformation used is based on a number of "hinge" points selected within each  $\phi$  plane being computed that lie within the body profile and closely model the body shape. These hinge points may either be input by the user or are generated

automatically by the code, except when the offset centerline geometric option is used (in which case the hinge points will be generated automatically in the computational coordinate system). The conformal transformation will, in general, be non-axisymmetric (IMAP = 1; default value), unless the user specifies an axisymmetric transformation (IMAP = 0) or the nosetip geometry is axisymmetric.

#### 4.3.1 Automatic Generation of Hinge Points

The standard option in CM3DT is to have the hinge points generated automatically, selected by setting IHINGE = 0 (default value). The hinge points to be generated, illustrated in Figure 4.7, consist of one point on the centerline in front of the body, one on the centerline inside the body, and the rest equally spaced in body wetted length, located inside the body along inward body normals. The last hinge point is located downstream of the end of the body geometry to ensure a smooth transformation. If the offset centerline geometric option is used, the hinge points must be generated automatically.

The number of hinge points generated in each plane is determined by the input JA; JA+2 hinge points will be generated in each plane. The maximum value of JA is 7. If an axisymmetric body geometry is specified, the hinge point locations will be the same in each  $\phi$  plane (axisymmetric mapping).

The first hinge point is located at a distance of TEST (8) \*  $\Delta_0$  forward of the body, where  $\Delta_0$  is an estimate of the shock stand-off distance computed automatically within the code as a function of  $M_\infty$  and RN, the effective nose radius. Subsequent hinge points are located a distance of DELH\*RN along inward body normals equally spaced in wetted length along the body surface.

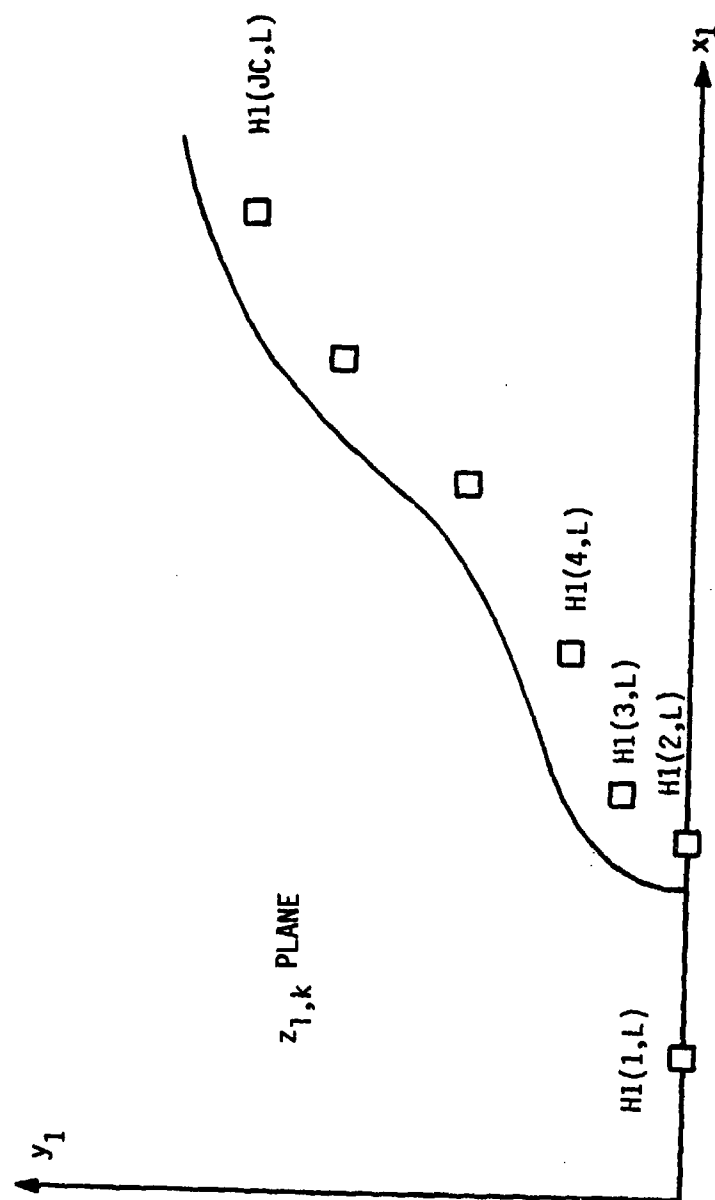


FIGURE 4.7. HINGE POINT LOCATIONS IN  $\phi = \phi_L$  PLANE

#### 4.3.2 Input Hinge Points

The user may, if the offset centerline geometric option is not used, input the hinge point locations. This option is exercised by setting  $IHINGE = 1$  and specifying values for  $H1(I,L)$ , the hinge point locations in  $(x,y)$  space for each of  $NPHI$  planes. Note that  $H1$  is a complex array, where  $H1 = x+iy$ .  $JA$  must also be specified with this option.

If an axisymmetric mapping is desired, the parameter  $IMAP$  is set to 0 and only one plane of  $H1$  data need be input. (An axisymmetric mapping is assumed if the body geometry is axisymmetric.) For a non-symmetric mapping,  $NPHI$  (see Section 4.3.3) planes of  $H1$  data must be specified, and each plane must contain  $JA+2$  hinge points. The  $H1$  points are input in the order shown in Figure 4.7.

#### 4.3.3 Definition of Computational Grid

Calculations in CM3DT are performed in a computational grid constructed in the transformed  $(\xi, \eta, \theta)$  space, as described in Reference 1. The coordinate surfaces are then defined by  $\theta = \text{constant}$  surfaces ( $\phi$  planes),  $\xi = \text{constant}$  surfaces (which are nearly normal to the body), and  $\eta = \text{constant}$  surfaces (which are nearly parallel to the body). Note that these surfaces, when transformed back to the physical  $(x,y,\phi)$  space, result in curved coordinate surfaces, as illustrated in Figure 4.8.

The number of grid points used in the calculation are specified by the parameters  $LMAX$ ,  $MMAX$ , and  $NMAX$ .  $LMAX$  meridional planes are equally spaced circumferentially on the body,  $MMAX$  surfaces are equally spaced in  $\xi$  within each meridional plane along the body surface, and  $NMAX$  points are equally spaced in  $\eta$  between the body and shock along each  $\xi = \text{constant}$  curve within each meridional plane. The maximum allowable values for  $LMAX$ ,  $MMAX$ , and  $NMAX$  are 9, 18, and 11, respectively.

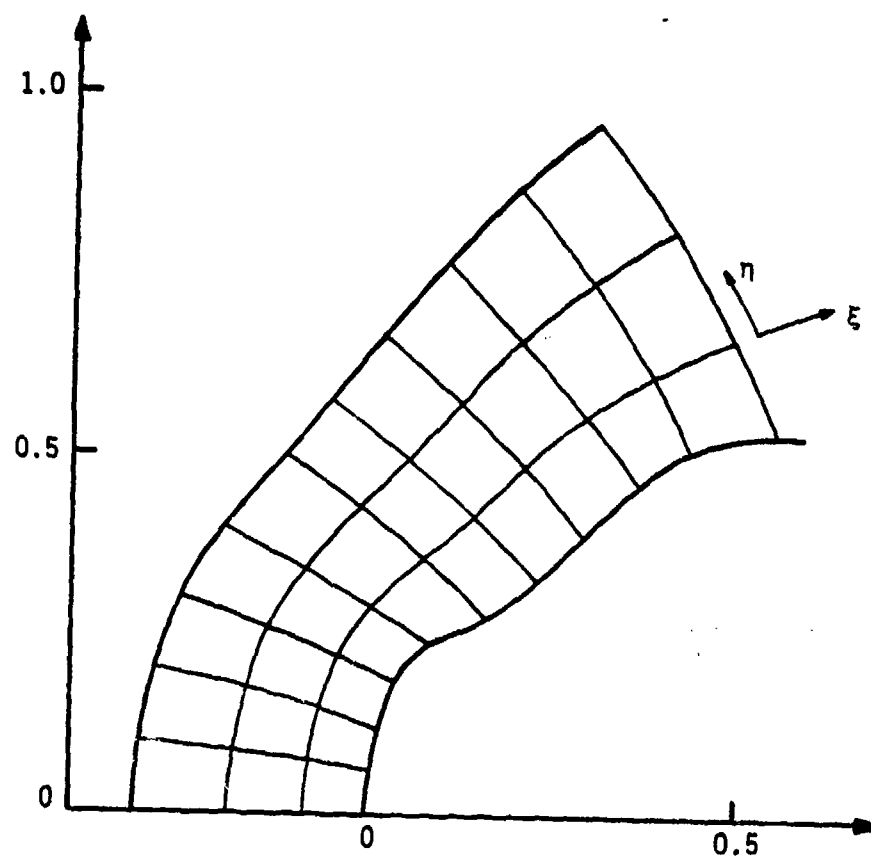


FIGURE 4.8.  $(\xi, \eta)$  COORDINATE GRID

The parameter ISA is used to denote those cases in which a pitch plane of symmetry exists. For ISA = 1, the body geometry must be symmetric about the pitch plane, there must be no sideslip (BETA = 0.0), the angle  $\delta_2$  must be zero, and, if NPHI < 0, there must be no geometric offset of the cross-sections in the yaw plane (D2 = 0); all other cases require ISA = 2. With a pitch plane of symmetry, calculations are performed only between  $\phi = 0^\circ$  and  $\phi = 180^\circ$ ; with ISA = 2,  $\phi$  varies between  $0^\circ$  and  $360^\circ$ .

For those cases with ISA = 1, LMAX must be specified as an odd integer; with ISA = 2, LMAX must be an integer multiple of 4. (These restrictions arise from the numerical treatment of the centerline.) The CM3DT program will automatically correct the value of LMAX specified to satisfy these criteria if necessary. However, if the corrected value of LMAX exceeds the maximum allowed (9), the program will stop.

#### 4.4 OUTPUT CONTROLS

In the CM3DT code, complete field output is provided every KOUT steps, starting with step 0, as well as at the last time step. The amount of output provided is determined by the parameter JOUT. For JOUT = 0, only the primary flow variables at each grid point are printed (p,u,s/R,etc.), as well as information regarding the position and velocity of shock points and the shock slopes.

When JOUT = 1, the output will also include parameters of the coordinate transformation ( $\xi, \eta, g, \tilde{C}, \tilde{S}, \phi$ ). For non-symmetric mappings (IMAP = 1), information on the circumferential variations of the mapping at each grid point ( $g_\phi, \zeta_\phi$ ) will be printed for JOUT = 2. Note that specification of an axisymmetric mapping (IMAP = 0) precludes exercising the JOUT = 2 option, since all circumferential derivatives of the transformation would then vanish.

A complete description of the variables output using these various options may be found in Section 5.0.



In addition to the printed output, CM3DT can also generate output on a binary file. The binary file output is necessary for restarts (Section 4.5.1) and for generating the required initial data for supersonic afterbody calculations (Section 6.0). The parameter controlling the generation of binary file output is KTAPE. No binary file output is created if KTAPE<0; otherwise, complete flow field data is written on the file every KTAPE time steps.

#### 4.5 OTHER PROGRAM CONTROLS

##### 4.5.1 Time Step Controls

The number of time steps to be taken by the CM3DT code is governed by the inputs KSTART and KMAX. KSTART denotes the number of the time step at which the calculation begins; if KSTART is not input the solution is automatically initialized at step 0, and a value of KSTART greater than zero indicates a restart of a previous solution from binary file output. For a restart, KSTART must correspond to one of the time steps stored on the binary file.

The last time step to be taken is denoted by KMAX. When this step is reached, the solution is terminated, the field data at that step is output, and (if KTAPE>0) the solution is written on the binary file.

The size of the time step is controlled internally by the CM3DT program. The computed time step may be altered by the factor STAB at the discretion of the user; however, values of STAB greater than 1.0 may lead to unstable calculations. In normal applications, the user need not be concerned with modifying the default value of this parameter (1.0).

During the calculation, the computational scheme requires that after each time step an inverse mapping (from  $(\xi, \eta, \theta)$  space to  $(x, y, \phi)$  space) be performed to update the transformation parameters and relocate the grid points in physical space as the grid varies with time. For increased

efficiency, however, this inverse mapping need not be performed after every time step. The input parameter KGRID (preset to 10) defines the number of time steps to be taken between calls to the inverse mapping subroutine.

#### 4.5.2 Solution Initialization

When starting a solution from step 0, the CM3DT code automatically generates an estimate of the complete flow field to provide the required initial data. Only one user input is required for this initialization, the effective nose radius, RN. The value of RN controls the estimate of the shock stand-off distance at the centerline, which is based on a correlation of stand-off distances for spheres vs. Mach number. Thus, RN should represent the effective radius of the nosetip being computed at the centerline.

#### 4.5.3 $\lambda$ -Scheme Calculations

Two calculation procedures are available within the CM3DT program: the non-conservation code (ILAM = 0) and the  $\lambda$ -differencing code (ILAM = 1). Because of its slightly greater efficiency, the non-conservation option is the preferred procedure for convex body shapes (no embedded shocks) without sharp corners. For indented shapes, where embedded shocks are anticipated, the  $\lambda$ -differencing procedure is required. Furthermore, the  $\lambda$ -scheme offers the advantage of minimizing oscillations in the solution when corners are present in the body geometry that are not adequately resolved with the computational grid.

#### 4.5.4 Shock Tables

In equilibrium real gas calculations, downstream shock point properties are determined from interpolation on a table of shock properties as functions of the normal component of freestream velocity relative to the moving shock. The number of entries in the table can be specified through the input parameter NUWTB, which is preset to 91. The upper and lower limits

on the table are specified as UWTBMX and UWTBMN, respectively, and are preset to 1.2 and 0.1. (These values represent the extremes in the ratio of the normal velocity component relative to the shock to the freestream velocity.)

## SECTION 5

### CODE OUTPUT

Standard output of the CM3DT code includes printout of the input variables and body geometry data, parameters of the coordinate transformation, a brief time history of the calculation, and complete field data every KOUT steps. Optional outputs are available if requested by the user, as described below. A glossary of output variables is provided in the Appendix (Section 10.2), and examples of the code output are also provided in the Appendix (Section 10.5).

#### 5.1 PRELIMINARY OUTPUT

##### 5.1.1 Input Variables

The first page of output generated by the CM3DT code lists values of input variables defined by the user, as well as information computed internally by the code based on the input parameters. First, information on all of the freestream properties is provided, followed by data concerning the thermodynamic model (ideal or real gas) selected for the calculation.

Information is then provided about the angle of attack and yaw angle relative to the nosetip centerline as computed by the code from the input angles of attack and sideslip (which are defined relative to the afterbody axis). Following this, the input variables defining the computational coordinate grid, the number of time steps to be taken, and the output controls are listed.

This first page of output also provides values of the theoretical stagnation pressure (PSTAG) and total enthalpy (HTOT), as well as values of normal shock pressure (PSH), entropy (SRSH), and Mach number (AMSH), as computed internally by the code from the specified freestream conditions.

Finally, this page of output concludes with explicit statements of the options that have been specified by the user.

#### 5.1.2 Body Geometry Definition

The next section of the output details the specification of the body geometry for the calculation. For an analytic, axisymmetric geometry, the values of the coefficients (ACOF) of each curve segment are printed, as well as the x-values of each segment end point.

For arbitrary body geometries without an offset centerline, the tabulated values of XB and YB in each PHI plane specified by the user are printed, followed by a statement of which arbitrary body geometry option, as described in Section 4.1.2, is used.

For arbitrary body geometries with an offset centerline, the values of the arrays D1, D2, AE, BE, CE, and DE are printed out at each axial station, XE(I). Information is also printed out defining the orientation of the new computational nosetip axis relative to the afterbody axis, as well as the values of  $\alpha$  and  $\beta$  relative to the computational axis, as computed automatically within CM3DT.

#### 5.1.3 Conformal Transformations

Following the body geometry information, the output provides information on the hinge points (whether generated automatically by the code or input by the user) in the physical (x,y, $\phi$ ) space, as well as the hinge point locations after each intermediate conformal transformation. The exponents (POWER) of each intermediate transformation in each meridional plane are also provided. Note that the hinge points are printed as H(I,J,L), a complex number, where the subscripts identify the I<sup>th</sup> hinge point after the (J-1)<sup>th</sup> transformation in the L<sup>th</sup> meridional plane.

The final portion of this section of output defines the stretching parameters (AL) used in the final transformation in each meridional plane, as well as information defining the downstream boundary of the region being computed in the transformed space (XIL, XILTH).

#### 5.1.4 Transformed Body Geometry Information

The last part of the preliminary output of the CM3DT code provides body geometry information at each computational grid point located on the body surface. This information is output for each meridional plane being computed, and includes data on the location of the point and the geometric derivatives in both the physical space (XB, YB, DYDX, DYDPH) and in the transformed space (XIB, ETAB, ETABXI, ETABTH).

### 5.2 STANDARD OUTPUT

#### 5.2.1 Field Data

Complete field data is output by the CM3DT code every KOUT time steps, starting with step 0, as well as at the final time step, KMAX. Within every meridional plane, the data output consists of the location of every grid point in physical space (X,Y), the local static pressure (P), entropy (SR), density (RH0), and Mach number (MACH), and the velocity components in ( $\xi, \eta, \theta$ ) space (U,V,W). In addition, the variation between the computed and theoretical values of total enthalpy, ratioed to the known theoretical total enthalpy, is provided as a measure of convergence (DH).

Information is also provided within each meridional plane on the shock position, velocity, and slopes in the transformed space. The shock position is defined by XIS and ETAS, and the shock velocity in the transformed space along  $\xi = \text{constant}$ ,  $\theta = \text{constant}$  curves is given as ETAST. This transformed shock velocity corresponds to physical shock velocity ETSTOG. Shock slopes in the transformed space are given by ETASXI and ETASTH.

### 5.2.2 Time History Output

To provide a history of the time-dependent calculation, the CM3DT code prints at every time step values of four quantities that provide a means of judging the convergence of the solution. (Convergence criteria for this code are discussed in Section 6 of Volume I of this report.) The four quantities printed are PSTAG (pressure at the centerline body point), DELTA (distance between the body and the bow shock at the centerline), WRMS (root-mean-square of the shock velocities), and ESTOGM (the maximum shock velocity). The convergence of PSTAG and DELTA indicate the potential convergence of the calculation in the vicinity of the centerline, while WRMS and ESTOGM serve as indications of the asymptotic approach of the entire solution to the steady state limit.

## 5.3 OPTIONAL OUTPUT

### 5.3.1 Optional Field Output

Optional field output will be generated by the CM3DT code when the input parameter JOUT is set to 1 or 2. This optional field output is printed immediately following the standard field output, every KOUT time steps.

With JOUT = 1, information is provided on the conformal transformations within each meridional plane. Specifically, at every grid point, values are printed for the  $(\xi, \eta)$  location of the point in transformed space  $(XI, ETA)$ , and information on derivatives of the transformation within that meridional plane. These derivatives are  $g = \frac{\partial \zeta}{\partial z} = Ge^{i\omega}$  and  $\phi = \partial(\log g)/\partial \zeta$ , and outputs are provided for the magnitude of  $g$  (AG), the real and imaginary parts of  $g$  (REG, IMG), the real and imaginary parts of  $e^{-i\omega}$  (CIS1, CIS2), and the real and imaginary parts of  $\phi$  (PHI1, PHI2).

If JOUT = 2, the same information provided with JOUT = 1 is printed, as well as information concerning the circumferential derivatives of the transformation. Values are printed for the real and imaginary parts of  $\partial \zeta / \partial \phi$  (REZETPHI, IMZETPHI) and for the real and imaginary parts of  $\partial g / \partial \phi$  (REGPHI, IMGPHI) at every computational grid point when this option is exercised. Note that the JOUT = 2 option cannot be invoked if an axisymmetric coordinate mapping (IMAP = 0) has been specified, since these derivatives then vanish.

### 5.3.2 Shock Table Output

If a real gas calculation is being performed (IRG = 1), the user may have the shock property tables printed by specifying ITBOUT = 1. When this option is selected, values of pressure (P), entropy (S/R), the isentropic exponent (G), and the downstream normal component of velocity relative to the shock (UN2) are printed out as functions of the upstream normal component of velocity relative to the shock (UN1).



## SECTION 6

### COUPLING OF NOSETIP CODE TO SUPERSONIC AFTERBODY CODE

The CM3DT nosetip flow field code has been coupled to the supersonic afterbody code described in References 2 and 3 to provide a capability for the prediction of total vehicle aerodynamics for reentry vehicles with ablated nosetips. This coupling requires interpolation on the nosetip solution to provide the required initial flow information at the starting line of the afterbody code. The relationship between the nosetip computational  $(x,y,\phi)$  and afterbody  $(r,\theta,z)$  cylindrical coordinate systems is described below, as well as the inputs required to couple CM3DT to the afterbody solution.

As discussed in Section 4, the nosetip computational axis may be rotated from the afterbody axis in both pitch and yaw, the angles of rotation being denoted by  $\delta_1$  (DEL1) and  $\delta_2$  (DEL2), respectively. (Note that if the computational axis differs from the geometric definition axis, the values of  $\delta_1$  and  $\delta_2$  are recomputed within CM3DT, as described in the Appendix, Section 10.4.) The angles of attack ( $\alpha$ ) and sideslip ( $\beta$ ) required as input to the CM3DT code are defined relative to the unbent afterbody axis.

For the nosetip calculation, however, CM3DT requires the effective angles of attack ( $\alpha_N$ ) and sideslip ( $\beta_N$ ) relative to the nosetip centerline. These quantities are computed internally by CM3DT from

$$\begin{aligned} \sin \beta_N &= \sin \beta \cos \delta_2 + \cos \alpha \cos \beta \sin \delta_2 \cos \delta_A \\ &\quad - \sin \alpha \cos \beta \sin \delta_2 \sin \delta_A \end{aligned} \quad (6.1)$$

$$\tan \alpha_N = V_y/V_x \quad (6.2)$$

where

$$\begin{aligned} V_y = V_\infty [ & \cos \alpha \cos \beta (\sin \delta_1 \cos \delta_2 \cos \delta_A + \cos \delta_1 \sin \delta_A) \\ & + \sin \alpha \cos \beta (-\sin \delta_1 \cos \delta_2 \sin \delta_A + \cos \delta_1 \cos \delta_A) \\ & - \sin \beta \sin \delta_1 \sin \delta_2 ] \end{aligned} \quad (6.3)$$

$$\begin{aligned} V_x = V_\infty [ & \cos \alpha \cos \beta (\cos \delta_1 \cos \delta_2 \cos \delta_A - \sin \delta_1 \sin \delta_A) \\ & + \sin \alpha \cos \beta (-\cos \delta_1 \cos \delta_2 \sin \delta_A - \sin \delta_1 \cos \delta_A) \\ & - \sin \beta \cos \delta_1 \sin \delta_2 ] \end{aligned} \quad (6.4)$$

It is required that the nosetip computational axis intersect the afterbody axis; this point of intersection has an  $x$  value of  $x_0$  ( $X0$ )\* in the nosetip  $(x,y,\phi)$  coordinate system and a  $z$  value of  $z_0$  ( $Z0$ ) in the afterbody  $(r,\theta,z)$  coordinate system. If the afterbody axis is bent, the bend occurs at a  $z$  value of  $\bar{z}$  ( $ZB$ ). These parameters are illustrated in Figure 4.1, and must be included in the input to the afterbody code.

The relationship between the afterbody  $(r,\theta,z)$  cylindrical coordinate system and the  $(x,y,\phi)$  nosetip computational cylindrical coordinate system is described in the Appendix, Section 10.4.

In the generation of starting line data for the afterbody code, it is necessary to completely define the shock layer flow in a  $z = \text{constant}$  surface, at grid points located at known  $\theta$  values at known percentages of the shock layer thickness. The first step in generating the starting line data is to locate the shock position in the initial data plane; i.e.,  $r = r_s(\theta,z)$  for the known values of  $z$  and  $\theta$ . This requires an iterative

---

\*The parameter  $X0$  in the afterbody code is identical to the parameter  $XH0$  in the CM3DT code.

procedure, assuming a value of  $r_s$ , determining the corresponding values of  $(x, y, \phi)$  and checking the value of  $y$  so determined against the shock position in the nosetip coordinate system,  $y = y_s(x, \phi)$ . Once the shock position in the initial data plane has been determined, the location of all afterbody grid points in the initial data plane is known.

Knowing  $(r, \theta, z)$ , the corresponding value of  $(x, y, \phi)$  can be calculated, and the flow variables  $P, s, u', v'$ , and  $w'$  can be determined by interpolation on the nosetip solution. The nosetip transformed velocity components  $(u', v', w')$  may be used to compute the nosetip cylindrical velocity components  $(U, V, W)$  from

$$U = u' \tilde{C} - v' \tilde{S} \quad (6.5)$$

$$V = u' \tilde{S} + v' \tilde{C} \quad (6.6)$$

$$W = w \quad (6.7)$$

(where  $\tilde{C} + i\tilde{S} = e^{-i\omega}$ ). The afterbody cylindrical velocity components  $u$  (radial) and  $v$  (circumferential) are computed from

$$u = \cos \theta V_y + \sin \theta V_z \quad (6.8)$$

$$v = -\sin \theta V_y + \cos \theta V_z \quad (6.9)$$

where

$$\begin{aligned} V_y = & U(-\sin \delta_A \cos \delta_1 \cos \delta_2 - \cos \delta_A \sin \delta_1) \\ & + (V \cos \phi - W \sin \phi)(-\sin \delta_A \sin \delta_1 \cos \delta_2 + \cos \delta_A \cos \delta_1) \\ & - (V \sin \phi + W \cos \phi) \sin \delta_A \sin \delta_2 \end{aligned} \quad (6.10)$$

$$\begin{aligned} V_z = & -U \cos \delta_1 \sin \delta_2 - (V \cos \phi - W \sin \phi) \sin \delta_1 \sin \delta_2 \\ & + (V \sin \phi + W \cos \phi) \cos \delta_2 \end{aligned} \quad (6.11)$$

The afterbody axial component  $w$  can be determined from the conservation of total enthalpy, expressed as

$$H = h(p,s) + \frac{1}{2} (u^2 + v^2 + w^2) \quad (6.12)$$

where  $H$  is the total enthalpy, which is constant and equal to the free-stream total enthalpy for a steady inviscid flow.

Forces and moments on the nosetip are determined by integration in the nosetip coordinate system, referencing the moments to the center of gravity location specified in the afterbody code by  $(\bar{x}, \bar{y}, \bar{z})$ , as shown in Figure 6.1. The relationship between the nosetip computational and afterbody coordinate systems is detailed in Section 10.4;  $(\bar{x}_2, \bar{y}_2, \bar{z}_2)$  represents the center of gravity location in the nosetip coordinate system.

The force integrals, evaluated relative to the nosetip computational axes and using the sign conventions depicted in Figure 6.2, may be expressed as

$$F_{A_N} = \int_0^{2\pi} \int_{x_{B_0}}^{x_E(\phi)} p y_b y_{b_x} dx d\phi \quad (6.13)$$

$$F_{N_N} = - \int_0^{2\pi} \int_{x_{B_0}}^{x_E(\phi)} p y_b (\cos\phi + \sin\phi y_{b\phi}/y_b) dx d\phi \quad (6.14)$$

$$F_{Y_N} = \int_0^{2\pi} \int_{x_{B_0}}^{x_E(\phi)} p y_b (\sin\phi - \cos\phi y_{b\phi}/y_b) dx d\phi \quad (6.15)$$

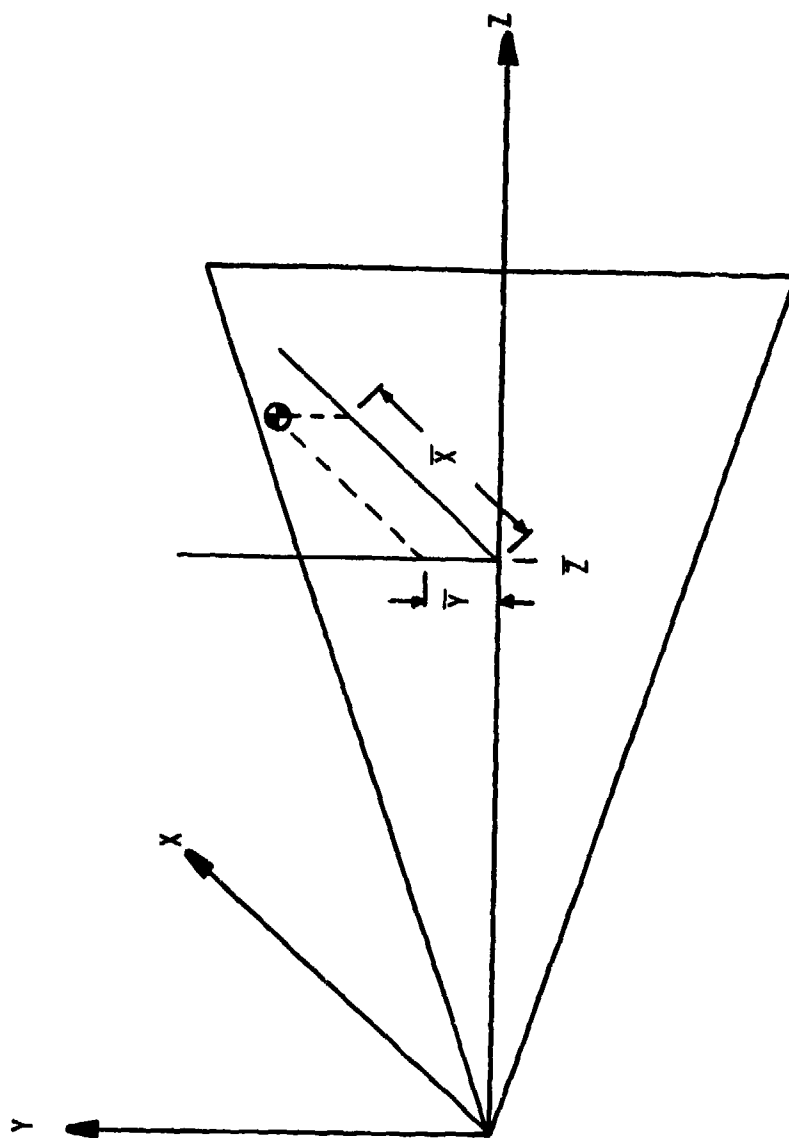


FIGURE 6.1. AFTERBODY CARTESIAN COORDINATE SYSTEM

$\alpha$ : POSITIVE NOSE UP

$\beta$ : POSITIVE NOSE LEFT

SYMMETRIC VEHICLE

$+\alpha \Rightarrow +C_N, -C_m$

$+\beta \Rightarrow -C_Y, +C_n$

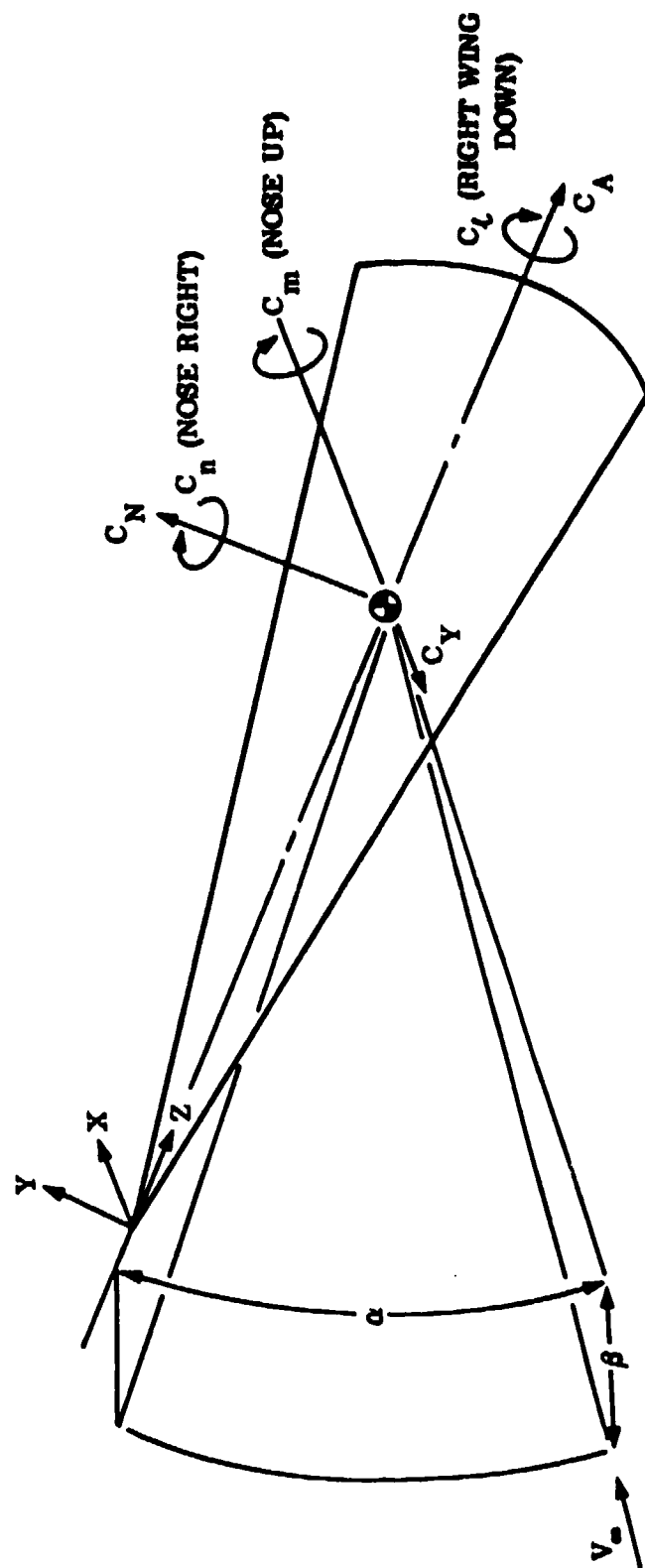


FIGURE 6.2. FORCE AND MOMENT SIGN CONVENTIONS

where  $F_{AN}$ ,  $F_{NN}$ , and  $F_{YN}$  represent the axial, normal, and side forces on the nosetip, respectively. In these expressions,  $p$  is the surface pressure,  $x_{B_0}$  is the  $x$  value of the centerline body point, and  $x_E(\phi)$  is the  $x$  value at the body surface in the afterbody initial data plane, expressed in the nosetip coordinate system. The nosetip moment integrals may be expressed as

$$M_{Z_N} = \int_0^{2\pi} \int_{x_{B_0}}^{x_E(\phi)} p y_b [x(\cos\phi + \sin\phi y_{b\phi}/y_b) + y_b y_{bx} \cos\phi] dx d\phi + (x_0 + \bar{x}_2) F_{NN} - \bar{y}_2 F_{AN} \quad (6.16)$$

$$M_{Y_N} = - \int_0^{2\pi} \int_{x_{B_0}}^{x_E(\phi)} p y_b [x(\sin\phi - \cos\phi y_{b\phi}/y_b + y_b y_{bx} \sin\phi] dx d\phi + (x_0 + \bar{x}_2) F_{YN} + \bar{z}_2 F_{AN} \quad (6.17)$$

$$M_{X_N} = - \int_0^{2\pi} \int_{x_{B_0}}^{x_E(\phi)} p y_b^2 [2\sin\phi \cos\phi + (\sin^2\phi - \cos^2\phi) y_{b\phi}/y_b] dx d\phi - \bar{z}_2 F_{NN} - \bar{y}_2 F_{YN} \quad (6.18)$$

where  $M_{Z_N}$ ,  $M_{Y_N}$ , and  $M_{X_N}$  represent the nosetip pitching, yawing, and rolling moments, respectively, using the sign conventions depicted in Figure 6.2, with  $\bar{x}_2$ ,  $\bar{y}_2$ , and  $\bar{z}_2$  defining the center of gravity location in the nosetip Cartesian coordinate system.

These nosetip forces and moments can be expressed relative to the afterbody coordinate system as

$$\begin{aligned} F_A' = & (\cos \delta_1 \cos \delta_2 \cos \delta_A - \sin \delta_1 \sin \delta_A) F_{A_N} \\ & + (\sin \delta_1 \cos \delta_2 \cos \delta_A \\ & + \cos \delta_1 \sin \delta_A) F_{N_N} - \sin \delta_2 \cos \delta_A F_{Y_N} \end{aligned} \quad (6.19)$$

$$\begin{aligned} F_N = & - (\cos \delta_1 \cos \delta_2 \sin \delta_A + \sin \delta_1 \cos \delta_A) F_{A_N} \\ & - (\sin \delta_1 \cos \delta_2 \sin \delta_A \\ & - \cos \delta_1 \cos \delta_A) F_{N_N} + \sin \delta_2 \sin \delta_A F_{Y_N} \end{aligned} \quad (6.20)$$

$$\begin{aligned} F_Y = & \cos \delta_1 \sin \delta_2 F_{A_N} + \sin \delta_1 \sin \delta_2 F_{N_N} \\ & + \cos \delta_2 F_{Y_N} \end{aligned} \quad (6.21)$$

$$\begin{aligned} M_Z' = & -\cos \delta_1 \sin \delta_2 M_{X_N} - \sin \delta_1 \sin \delta_2 M_{Y_N} \\ & + \cos \delta_2 M_{Z_N} \end{aligned} \quad (6.22)$$

$$\begin{aligned} M_Y' = & - (\cos \delta_1 \cos \delta_2 \sin \delta_A + \sin \delta_1 \cos \delta_A) M_{X_N} \\ & - (\sin \delta_1 \cos \delta_2 \sin \delta_A - \cos \delta_1 \cos \delta_A) M_{Y_N} \\ & - \sin \delta_2 \sin \delta_A M_{Z_N} \end{aligned} \quad (6.23)$$

$$\begin{aligned} M_X = & (\cos \delta_1 \cos \delta_2 \cos \delta_A - \sin \delta_1 \sin \delta_A) M_{X_N} \\ & + (\sin \delta_1 \cos \delta_2 \cos \delta_A + \cos \delta_1 \sin \delta_A) M_{Y_N} \\ & + \sin \delta_2 \cos \delta_A M_{Z_N} \end{aligned} \quad (6.24)$$



The axial force ( $F_A'$ ), pitching moment ( $M_Z'$ ), and yawing moment ( $M_Y'$ ) of the nosetip in the afterbody coordinates are denoted by primes to indicate that these quantities have been computed assuming zero base pressure ( $p_b = 0$ ). In the afterbody code to which CM3DT has been coupled, however, forces and moments are computed assuming that  $p_b = p_\infty$ . For consistency, the axial force and yawing and pitching moments for the nosetip, expressed in the afterbody coordinates, can be modified to fit this assumption using

$$F_A = F_A' - \frac{1}{2} p_\infty \int_0^{2\pi} r_b^2(\theta) d\theta \quad (6.25)$$

$$M_Z = M_Z' - p_\infty \int_0^{2\pi} \left[ \frac{1}{3} r_b \cos\theta - \frac{1}{2} (\bar{Y} - d) \right] r_b^2(\theta) d\theta \quad (6.26)$$

$$M_Y = M_Y' + p_\infty \int_0^{2\pi} \left( \frac{1}{3} r_b \sin\theta + \frac{1}{2} \bar{X} \right) r_b^2(\theta) d\theta \quad (6.27)$$

where the integrals are to be evaluated at the initial data plane of the afterbody, in the afterbody cylindrical coordinate system ( $r, \theta, z$ ).

## SECTION 7

### INPUT GUIDE LIST AND SAMPLE CASES

#### 7.1 INPUT GUIDE (CM3DT)

The first input record is a title card which may contain up to 80 characters of alphanumeric information. Following the title card, the input variables are read in the NAMELIST format, where the NAMELIST group name is INPUT.

#### INPUT CHECKLIST

(Title Card; Alphanumeric information  
in columns 1-80)

\$INPUT

(Namelist Identifier)

(Freestream Conditions)

AMINF

QINF

IRG

IATMP

ALT

PINF

TINF

GIDEAL

RIDEAL

ZIDEAL

ALPHA

BETA

DELA

DEL1

DEL2

(Geometry - Analytic)

NSEG

ACOF(I,J)

ADIV(J)

(Geometry - Arbitrary, without Offset)

NPHI

PHIBD(L)

NPTS(L)

XB(I,L)

YB(I,L)

(Geometry - Arbitrary, with Offset)

NPHI

XE(I)

AE(I)

BE(I)

CE(I)

DE(I)

D1(I)

D2(I)

NPTS(1)

NSEG

ACOF(I,J)

ADIV(J)

XHO

(Grid Definition)

XBO

XBB(L)

NMAX

MMAX

LMAX

IMAP

IHINGE

H1(I,L)

DELH

JA

ISA

(Time-Step Controls)

KMAX

STAB

KSTART

KGRID

(Output Controls)

KOUT

JOUT

KTAPE

ITBOUT

(Miscellaneous Controls)

ILAM

RN

TEST(1)

(Shock Table Controls)  
(Real gas only)

NUWTB

UWTBMX

UWTBMN

(End of NAMELIST input)

7.2 INPUT GUIDE (AFTERBODY CODE)

The standard inputs to the afterbody code are defined in Reference 4. The version of this afterbody code modified for use with CM3DT has four additional input parameters that must be defined to relate the nosetip and afterbody coordinate systems. These inputs are:

ZB	$\bar{z}$ , Afterbody axial location where afterbody axis is bent
Z0	$z_0$ , Afterbody axial location where afterbody and nosetip axes intersect
X0	$x_0$ , Nosetip computational coordinate system axial location where afterbody and nosetip axes intersect (not required if off-set centerline nosetip geometry option used)
TEST(4)	Convergence criterion for shock position interpolation in generating starting line data, preset to 0.001.

### 7.3 SAMPLE CASES

In this section the inputs required for three sample calculations with the CM3DT code are presented, along with the inputs required for a sample afterbody calculation. The samples of output presented in the Appendix, Section 10.5, have been selected from these sample cases.

Case 1 - The first sample case is a sphere in ideal gas ( $\gamma = 1.4$ ) at  $M_\infty = 20$  in both pitch and yaw, with  $\alpha = 5^\circ$  and  $\beta = 5^\circ$ . The geometry is defined analytically, and an axisymmetric coordinate mapping is used. The non-conservation version of the code is used for this calculation.

#### INPUT FOR CASE 1

```
CM3DT(NC)    SPHERE    MACH 20    ALPHA=5    BETA=5
$INPUT
AMINF=20.0,ALPHA=5.0,BETA=5.0,
NSEG=1,ACOF(9,1)=1.0,0.5,0.5,
XBO=0.0,XBB(1)=0.5,IMAP=0,JA=5,
NMAX=5,MMAX=10,LMAX=8,ISA=2,
KMAX=300,KOUT=300,
ILAM=0,RN=0.5,$
```

Case 2 - The second case is a calculation of an ideal gas flow at  $M_\infty = 11.6$  over an axisymmetric indented shape, the Mildly Indented Body (MIB), depicted in Figure 7.1 and described in Reference 5, at  $\alpha = 2^\circ$ . An arbitrary, axisymmetric geometry definition is used, and an axisymmetric coordinate transformation is invoked. Since the MIB shape is indented, with an embedded shock, the  $\lambda$ -differencing calculation procedure is used.

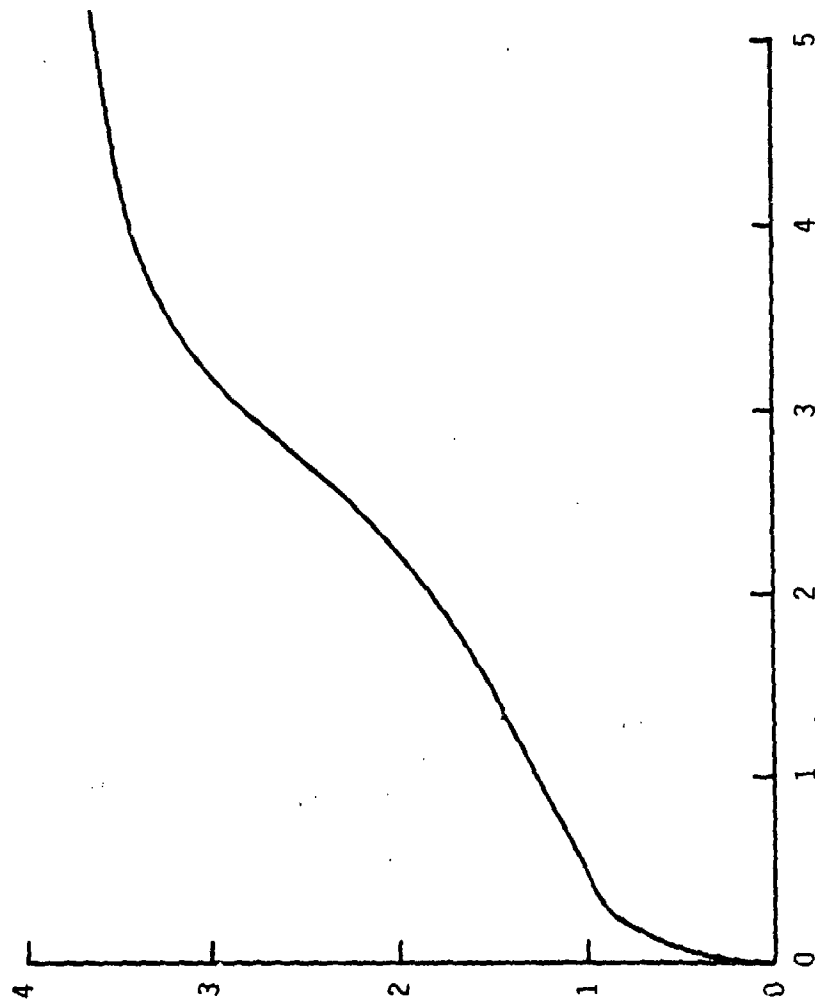


FIGURE 7.1. MIB CONFIGURATION

# INPUT FOR CASE 2

```

CM3DT(LAMBDA)  MIB  MACH 11.6  ALPHA=2
$INPUT
AMINF=11.6,ALPHA=2.0,
NPHI=1,NPTS(1)=30,
XB(1)=0.,.0065,.0269,.0617,.1096,.1701,.2672,.4218,.6113,.8154,
1.0382,1.2912,1.5692,1.8542,2.1395,2.4122,2.6584,2.8943,3.1255,
3.3684,3.6552,4.0,4.2,4.4,4.6,4.8,5.0,5.5,6.0,6.5,
YB(1)=0.,.1511,.3059,.4606,.6097,.751,.879,.9803,1.0727,1.1722,
1.2809,1.4043,1.5511,1.7299,1.942,2.1818,2.4318,2.6766,2.9076,
3.0984,3.2645,3.3985,3.4483,3.4793,3.5004,3.5214,3.5424,3.595,
3.6475,3.7001,
XB0=0.0,XBB(1)=9.6,IMAP=0,JA=7,
NMAX=11,MMAX=18,LMAX=9,
KMAX=500,KOUT=500,
ILAM=1,RN=1.75,$

```

Case 3 - The last sample case for the CM3DT code has been selected to demonstrate the use of an asymmetric conformal mapping procedure. The nosetip being computed is the Blunt-1 asymmetric shape, with offset circular cross-sections assumed (NPHI=2). The calculation is performed with the  $\lambda$ -differencing procedure, at a Mach number of 13.4 in ideal gas, at  $\alpha = 3^\circ$ . Note that the nosetip centerline is rotated in the pitch plane by  $\delta_1 = 9.648^\circ$  from the afterbody axis, leading to an effective nosetip angle of attack of  $\alpha_N = 12.648^\circ$ . This nosetip shape, and its orientation relative to the afterbody axis, is illustrated in Figure 7.2.

# INPUT FOR CASE 3

```

CM3DT(LAMBDA)  BLUNT-1 NOSE SHAPE  MACH 13.4  ALPHA=3
$INPUT
AMINF=13.4,ALPHA=3.0,DEL1=9.648,
NPHI=2,NPTS(1)=28,30,
XB(1,1)=.22,.23,.247,.28,.3,.34,.4,.427,.5,.7,.8,.9,1.0,1.1,1.15,1.2,
1.22,1.24,1.28,1.4,1.6,1.8,2.0,2.2,2.4,2.6,2.8,3.0,
YB(1,1)=0.,.2,.3,.4,.438,.5,.570,.6,.667,.81,.865,.92,.96,1.0,1.022,
1.038,1.043,1.05,1.06,1.095,1.15,1.208,1.265,1.321,1.377,1.433,
1.489,1.545,
XB(1,2)=.22,.23,.245,.26,.3,.34,.38,.42,.46,.6,.8,1.0,1.2,1.4,1.44,
1.48,1.53,1.56,1.6,1.65,1.7,1.74,1.8,1.9,2.0,2.2,2.4,2.6,2.8,3.0,
YB(1,2)=0.,.04,.1,.16,.245,.302,.345,.378,.412,.527,.695,.86,1.027,
1.195,1.23,1.26,1.3,1.32,1.342,1.363,1.375,1.38,1.377,1.372,1.365,
1.352,1.339,1.327,1.314,1.301,
XB0=0.22,XBB(1)=2.4,2.8,IMAP=1,JA=7,DELH=.15,
NMAX=6,MMAX=18,LMAX=9,
KMAX=500,KOUT=500,KTAPE=500,JOUT=2,
ILAM=1,RN=1.0,$

```



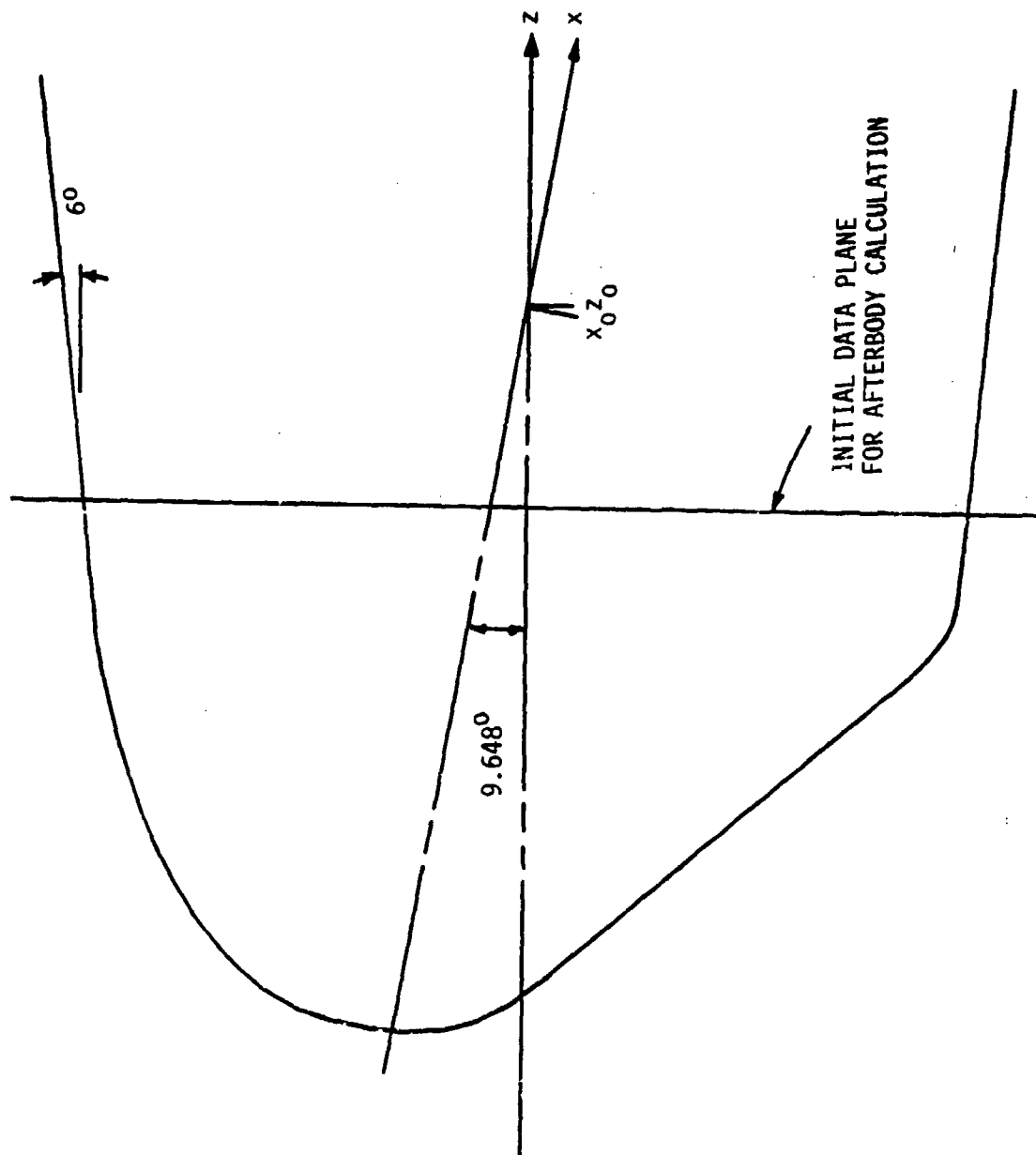


FIGURE 7.2. BLUNT-I CONFIGURATION

Case 4 - This sample case presents the inputs required to run the afterbody code, using the CM3DT code to generate the necessary initial data. This calculation is for a 6° cone (with no bend in the afterbody axis), with the Blunt-1 asymmetric nosetip attached. The afterbody calculation is performed at  $\alpha = 3^\circ$ , and the initial data is obtained from the CM3DT calculation described in Sample Case 3.

#### INPUT FOR CASE 4

```
MN3IS      BLUNT-1 NOSE SHAPE   6 DEG CONE   MACH 13.4   ALPHA=3
$IV
ISTART=500,
NMAX=11,MMAX=9,
MPRINT=0,
X0=2.4,Z0=13.357,
ZSTART=12.757,ZEND=47.0,
ALPHA=3,
YTAB(1,1)=-1.3408,YTAB(1,2)=-4.94,
ZXYTAB=12.757,47.0,
$
```

## SECTION 8

### DEFINITION OF APPLICABILITY OF CM3DT NOSETIP CODE

The CM3DT inviscid nosetip flow field code has extended the range of nosetip geometries for which successful inviscid flow field calculations can be performed by using a new coordinate system which can be closely aligned with the body geometry, and by using the  $\lambda$ -differencing scheme to compute embedded shocks on indented shapes in an approximate manner. Limitations do exist, however, in the application of this technique to ablated reentry vehicle nosetips.

As an inviscid technique, CM3DT is not capable of treating flows where viscous effects are important, such as separated or oscillating flows, as might occur on severely indented shapes. In addition, since CM3DT approximates embedded shocks as isentropic compressive discontinuities, the accuracy of the CM3DT results diminishes as the strength of an embedded shock grows.

This section details the results of an effort to define those indented nosetip shapes for which the CM3DT code can be expected to provide reliable flow field results. This effort is restricted to indented nosetip geometries, since CM3DT, by virtue of its unique body-oriented coordinate system, does not suffer from any limitations on its application to convex geometries, other than the requirement for having a sufficient number of mesh points to adequately resolve critical features of the flow field. (This restriction, of course, applies to all flow field techniques.)

The approach taken to define the applicability of the CM3DT technique to indented nosetip shapes was to perform calculations with an axisymmetric version of the CM3DT code on parametrically varying indented nosetip geometries. The generalized nosetip geometry used in these

calculations, taken from Reference 6, is shown in Figure 8.1, and is defined in terms of the nose radius ( $R_N$ ), the fillet radius ( $R_F$ ), the shoulder radius ( $R_S$ ), the cone angles ( $\theta_1, \theta_2$ ), the nosetip length ( $\ell$ ), and the fineness ratio ( $\ell/d$ ). Most indented nosetip geometries can be modeled (albeit approximately) with this parametric representation.

All calculations were performed with constant nose radius ( $R_N = 0.5$ ); because of the lack of an intrinsic length scale in inviscid flows, the effects of variation in  $R_N$  can be investigated by keeping  $R_N$  constant and varying other parameters. The shoulder radius was also held constant for these calculations ( $R_S = 0.5$ ), since this parameter does not significantly affect the flow in the indented region.

The bulk of the calculations were performed with zero fillet radius ( $R_F = 0$ ), corresponding to a sharp compression corner in the body geometry. A limited number of calculations were performed with a non-zero fillet radius, providing a direct comparison of the effects of a gradual versus a sharp compression on the flow field computation.

Most calculations were made at  $M_\infty = 10$ , assuming ideal gas thermodynamics. Several calculations were made at  $M_\infty = 5$  and  $M_\infty = 20$  in order to assess the effects of freestream Mach number on the flow field results.

Since only indented shapes were of interest in this study, the configurations considered were constrained by the requirement that  $\theta_2 > \theta_1$ . Furthermore, since embedded shocks can occur only when the shock layer flow upstream of the shock is supersonic, values of  $\theta_1$  greater than  $40^\circ$  were not considered.

Use was made of an axisymmetric version of CM3DT in order to minimize the computer resources required for this effort. However, all axisymmetric calculations were performed using no more mesh points along the body (MMAX) and between the body and the shock (NMAX) than are available within the CM3DT code, so that the results obtained can be applied

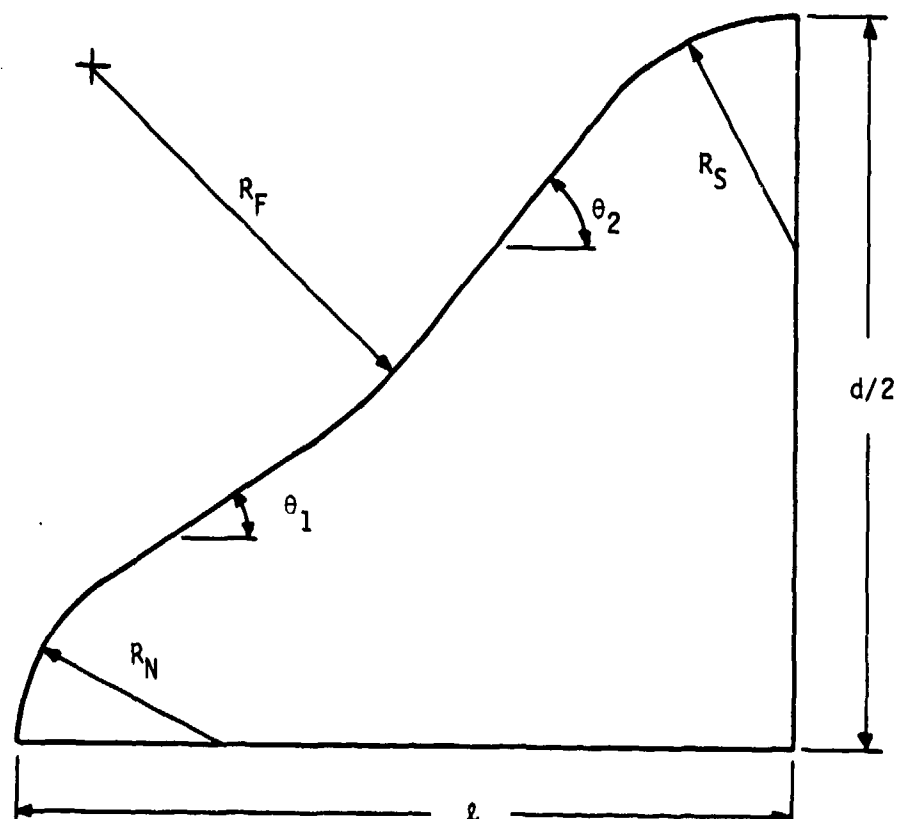


FIGURE 8.1. GENERALIZED INDENTED NOSETIP  
GEOMETRY

directly to the CM3DT code. The effects of angle of attack on the applicability of the CM3DT code were assessed by examination of three-dimensional calculations performed as part of the validation procedure for the CM3DT technique.

For each calculation, an assessment of the quality of the solution was made in order to determine if the solution was acceptable (i.e., was the numerical technique capable of providing an acceptable solution for that particular nosetip geometry). Although the evaluation of solution quality is subjective, several key parameters were carefully examined. In particular, values of DH (variation of computed total enthalpy from the known theoretical total enthalpy) and WRMS (root-mean-square of shock point velocities) were considered; ideally, these quantities should vanish in the limit of a perfectly converged solution.

As discussed in Volume I of this report (Reference 1), criteria on DH and WRMS have been developed to define a converged solution for the CM3DT code. (These criteria represent sufficient, but not necessary, conditions for convergence.) In the judgement of the suitability of the solutions obtained, these criteria were not adhered to rigidly. For example, the formal convergence criterion on DH requires that  $|DH|$  not exceed 0.05 at any mesh point in the solution; however, when approximating embedded shocks as isentropic discontinuities, as done in CM3DT,  $|DH|$  may be higher than 0.05, and the solution may still be judged acceptable.

For solutions that were judged to be unacceptable, it was noted that, as the degree of the indentation increased, the flow computed along the body surface frequently reversed. Any calculation with this flow reversal at the surface was deemed unacceptable. (Since the calculations are inviscid, this flow reversal should not be taken as an indication of separation, which is a viscous phenomenon. It is probable that this inviscid flow reversal is indicative of the limitations of the approximation to the embedded shock used in the CM3DT analysis.)

Based on the results of the axisymmetric calculations, it was determined that neither freestream Mach number nor nose radius had a significant effect on the ability of the technique to compute the flow on indented shapes. The results obtained from these calculations could most readily be correlated in terms of the maximum value of  $\theta_2$  for a given value of  $\theta_1$  for which successful calculations could be made (with  $R_F = 0$ ). A plot of  $\theta_{2MAX}$  versus  $\theta_1$  is given in Figure 8.2.

It is of interest to note that the curve shown in Figure 8.2 can be closely approximated by a straight line defined as  $\theta_{2MAX} = \theta_1 + 15^\circ$ . In a previous study evaluating the applicability of a blunt body code (Reference 7), it was determined that the mesh resolution required to obtain a valid finite difference solution must be fine enough to ensure that no mesh interval covers a region of flow turning angle of more than  $15^\circ$ . Although the code evaluated in Reference 7 is applicable only to convex geometries, the correspondence of the  $\Delta\theta = 15^\circ$  limitation arising in both the CM3DT evaluation and the previous effort is striking.

Investigations were also carried out to assess the effects of non-zero fillet radius on the ability of the technique to treat indented nosetip shapes. In general, it was discovered that the presence of a fillet could relax the  $\theta_{2MAX}(\theta_1)$  criterion for a successful calculation, provided that the fillet radius is large enough (and the mesh resolution fine enough) to have mesh points in the finite difference grid lying on the fillet, located such that  $\Delta\theta$  across a mesh interval is no larger than approximately  $15^\circ$ .

An example of the effects that can be expected from the presence of a fillet is provided by the Mildly Indented Body (MIB), an axisymmetric indented shape described in Reference 5. For this configuration, with  $\theta_1 = 26^\circ$  and  $\theta_2 = 46^\circ$ , the criterion shown in Figure 8.2 yields  $\theta_{2MAX} = 41^\circ$ , with a zero fillet radius. The MIB geometry, however, has a fillet radius of  $R_F = 4.375$  (with  $R_N = 1.75$ ), and the CM3DT code is known to give good

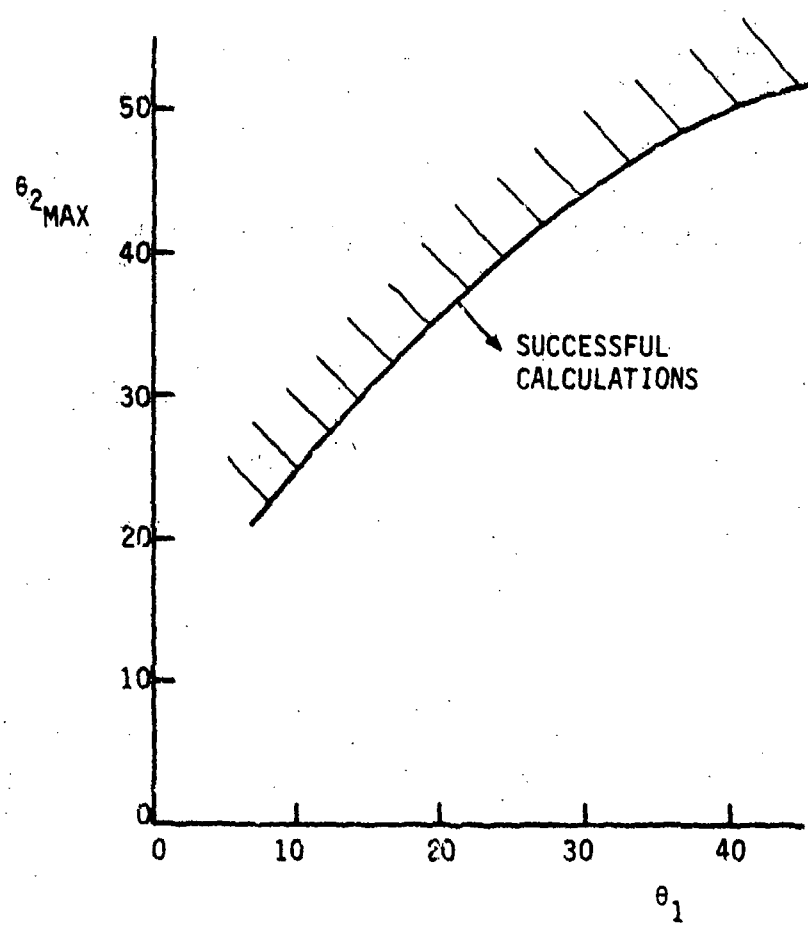


FIGURE 8.2. LIMITS OF APPLICABILITY OF THE CM3DT CODE TO INDENTED SHAPES



results for this case (as shown in Reference 1). Thus, the presence of the fillet has, in this case, extended the range of  $\theta_2$  for which successful calculations can be expected.

The presence of a sufficiently large fillet cannot, of course, totally relax limitations on the strength of the compressions that can be treated (i.e., the maximum value of  $\theta_2$  for which a calculation is feasible for a given value of  $\theta_1$ ). In general, the presence of a fillet should be expected to increase the maximum allowable value of  $\theta_2$  by no more than 20%.

The investigation of angle of attack effects on axisymmetric indented nosetip shapes revealed no large effects relative to the success of CM3DT calculations for a given geometric configuration. (It was noted, however, that as the angle of attack increased, more time steps were required to attain a satisfactory solution.) Because of the almost infinite number of possible geometric variations, no attempt was made to study angle of attack effects on asymmetric indented shapes.

Based on the results of this effort, the applicability of the CM3DT nosetip code to a given indented nosetip geometry can best be defined in terms of the  $\theta_{2MAX}$  versus  $\theta_1$  criterion depicted in Figure 8.2. Use of this criterion requires the user to approximate a particular geometry in terms of the parameters shown in Figure 8.1; for an asymmetric geometry, this characterization must be made in each meridional plane to be computed. The value of  $\theta_{2MAX}$  corresponding to the particular value of  $\theta_1$ , coupled with the potential ameliorating effects of a non-zero fillet radius, will provide a guide to the user as to whether or not CM3DT can be expected to provide a successful flow field calculation.

## SECTION 9

### REFERENCES

1. Hall, D. W., "Performance Technology Program (PTP-S II), Vol. III: Inviscid Aerodynamic Predictions for Ballistic Reentry Vehicles with Ablated Nosedtips," BMO TR-81-1, September, 1979.
2. Kyriass, C. L. and Harris, T. B., "A Three-Dimensional Flow Field Computer Program for Maneuvering and Ballistic Reentry Vehicles," presented at the 10th USN Aeroballistics Symposium, July, 1975.
3. Daywitt, J., Brant, D., and Bosworth, F., "Computational Technique for Three-Dimensional Inviscid Flow Fields about Reentry Vehicles, Volume I. Numerical Analysis," SAMSO TR-79-5, April, 1978.
4. Brant, D., Wade, M., and Moran, J., "Computational Technique for Three-Dimensional Inviscid Flow Fields about Reentry Vehicles, Volume II. User's Manual," SAMSO TR-79-5, April, 1978.
5. Reeves, B. L., Todisco, A., Lin, T. C., and Pallone, A., "Hyper-sonic Flow over Indented Nosedtips - STREET-A IV Experiments and Data Analysis," SAMSO TR-76-69, Volume X, April, 1976.
6. Reeves, B. L., "Analysis of Unsteady Flow Separation over Severely Indented Nosedtips," SAMSO TR-75-269, Volume VI, September, 1975.
7. Hall, D. W., Kyriass, C. L., Truncellito, N. T., and Martellucci, A., "Nose Trim Study, Volume II: An Evaluation of the G.E. Three-Dimensional Flow Field Program for Ballistic Reentry Vehicles with Asymmetric Noses," SAMSO TR-77-46, September, 1976.

## SECTION 10

### APPENDICES

#### 10.1 GLOSSARY OF INPUT VARIABLES

Default values are indicated in parentheses at right.

ACOF(I,J)	<u>i</u> th coefficient in <u>j</u> th segment of analytic axisymmetric body geometry definition (NSEG>0) or for centerline offset in pitch plane (NSEG<0);  NSEG  segments	
ADIV(J)	Abscissa of the end point of <u>j</u> th segment and the beginning point of the <u>j</u> th + 1st segment of analytic axisymmetric body geometry definition (NSEG>0) or for centerline offset definition (NSEG<0);  NSEG -1 values must be supplied	
AE(I)	Array of a values for arbitrary geometry option with centerline offsets (NPHI<0)	
ALPHA	$\alpha$ , Angle of attack (degrees), relative to afterbody centerline	(0.0)
ALT	h, Altitude (feet), if IATMP $\neq$ 0	
AMINF	$M_{\infty}$ , Freestream Mach number (required if QINF not input)	
BE(I)	Array of b values for arbitrary geometry option with centerline offsets (NPHI = -2, -3, -4)	
BETA	$\beta$ , Sideslip angle (degrees), relative to afterbody centerline	(0.0)

CE(I)	Array of c values for arbitrary geometry option with centerline offsets (NPHI = -3, -4)	
DE(I)	Array of d values for arbitrary geometry option with centerline offsets (NPHI = -4)	
DELA	$\delta_A$ , Bend angle (degrees) in pitch plane of afterbody axis	(0.0)
DELH	Spacing parameter for automatic generation of hinge points	(0.1)
DEL1	$\delta_1$ , Pitch angle of orientation of nosetip geometric axis relative to bent after- body axis (degrees)	(0.0)
DEL2	$\delta_2$ , Yaw angle of orientation of nosetip geometric axis relative to bent after- body axis (degrees)	(0.0)
D1(I)	Array of centerline offsets in pitch plane, NPHI < 0	
D2(I)	Array of centerline offsets in yaw plane, NPHI < 0	
GIDEAL	$\gamma$ , Ideal gas isentropic exponent	(1.4)
GMW	Gram molecular weight of equilibrium air	(28.9644)
H1(I,L)*	Location of ith hinge point, x+iy in Lth plane for IHINGE = 1; must have JC = JA+2 entries in each plane, NPHI planes	

-----  
\*Complex quantity

IATMP	Atmospheric freestream property assignment indicator: #0 Freestream pressure and temperature from 1962 standard atmosphere	(0)
IHINGE	Hinge point generation indicator =0 Hinge points generated automatically =1 Hinge points input	(0)
ILAM	$\lambda$ -differencing calculation indicator =0 for non-conservation calculation =1 for $\lambda$ -scheme calculation	(0)
IMAP	Coordinate transformation indicator =0 For axisymmetric mapping =1 For asymmetric mapping	(1)
IRG	Real gas option indicator =0 For ideal gas thermodynamics =1 For equilibrium air thermodynamics	(0)
ISA	Plane of symmetry indicator =1 Pitch plane of geometric symmetry and $\beta = 0$ =2 Asymmetric shape or $\beta \neq 0$	(1)
ITBOUT	Shock table output indicator (IRG = 1 only) =0 No shock table output =1 Shock tables output	(0)
JA	Number of "corners" defined by hinge points (maximum 7)	
JOUT	Field output indicator =0 Field data only output =1 Field data and transformation functions output =2 Field data, transformation functions, and circumferential transformation func- tions output	(0)

KGRID	Number of time steps between inverse coordinate transformations	(10)
KMAX	Maximum number of time steps	
KOUT	Number of time steps between complete output	(50)
KTAPE	Number of time steps between writing output on tape <0 No tape output	(-1)
KSTART	Step number for restart <0 Solution initialized at step 0	(-1)
LMAX	Number of circumferential planes in calculation (maximum 9)	(7)
MMAX	Number of grid points along body in each meridional plane (maximum 18)	(13)
NMAX	Number of grid points between body and shock (maximum 11)	(6)
NPHI	Number of planes of arbitrary body geometry input (maximum 9); NPHI>0 for no offset in geometric centerline, NPHI<0 for offset geometric centerline option =1 Axisymmetric arbitrary geometry =2 Circular cross-sections with centers offset from geometric centerline, pitch plane of geometric symmetry assumed =3 Bi-elliptic cross-sections, pitch plane of geometric symmetry assumed =4 and ISA = 2 Quad-elliptic cross-sections =4 and ISA = 1, or NPHI>4 Arbitrary cross-sections =-1 Circular cross-sections with offset geometric centerline =-2 Elliptic cross-sections with offset geometric centerline =-3 Bi-elliptic cross-sections with offset geometric centerline =-4 Quad-elliptic cross-sections with offset geometric centerline	(0)

NPTS(L)	<p>NPHI&gt;0, number of (XB,YB) points input in PHIBD(L) plane for arbitrary geometry option with no centerline offset (maximum value of 50)</p> <p>NPHI&lt;0, number of entries in XE, AE, BE, CE, DE, D1, and D2 arrays for arbitrary geometry option with centerline offset; only NPTS(1) required (maximum value of 50)</p>	
NSEG	<p>&gt;0 Number of segments used to define analytic axisymmetric body geometry (maximum 6)</p> <p>&lt;0 For NPHI&lt;0, number of segments used to define pitch plane centerline offsets for arbitrary body geometry (maximum value of  NSEG  is 6)</p>	(0)
NUWTB	Number of entries in shock table (real gas)	(91)
PINF	$p_{\infty}$ , Freestream static pressure (real gas, lbf/ft <sup>2</sup> )	(1.0)
PHIBD(L)	Circumferential planes for arbitrary geometry input (degrees); NPHI>0 (maximum of 9)	
QINF	$V_{\infty}$ , Freestream velocity (required if AMINF not input) (real gas, ft/sec)	(0.0)
RIDEAL	R, Gas constant (ideal gas)	(1.0)
RN	$R_N$ , Effective nose radius, used to estimate initial shock stand-off distance and locate hinge points, (HINGE = 0)	(0.5)
STAB	Stability factor in step-size calculation	(1.0)
TEST(1)	Convergence criterion for geometry iteration	(10 <sup>-6</sup> )
TEST(3)	$\epsilon$ for hinge points on horizontal axis	(10 <sup>-6</sup> )

TEST(8)	Factor on shock stand-off distance for automatic generation of H1(1,L)	(1.5)
TEST(11)	Convergence criterion for shock property iteration (real gas)	(10 <sup>-6</sup> )
TEST(12)	Convergence criterion for stagnation conditions iteration (real gas)	(10 <sup>-6</sup> )
TINF	T <sub>∞</sub> , Freestream static temperature (real gas, OR)	(1.0)
UWTBMN	Minimum value of $\tilde{u}/V_{\infty}^{**}$ , independent variable for shock tables	(0.1)
UWTBMX	Maximum value of $\tilde{u}/V_{\infty}^{**}$ , independent variable for shock tables	(1.2)
XB(I,L)	Abscissa of <i>i</i> th point in arbitrary geometry description in plane PHIBD(L); NPHI>0 (XB(1,L) = XB0)	
XBB(L)	Abscissa of body point in plane PHIBD(L) defining downstream boundary of the computational region (NPHI values to be specified if NPHI>0, one value if NPHI<0 or if NSEG>0)	
XB0	Location of body point on nosetip geometric axis	(0.0)
XE(I)	Array of $\lambda$ values for arbitrary geometry option with centerline offsets (NPHI<0) (NPTS(1) values)	
XH0	Value of $\lambda$ where nosetip geometric axis intersects bent afterbody axis	

-----  
 $\tilde{u}$  is the normal component of the freestream velocity relative to the shock



YB(I,L)      Ordinate of ith point in arbitrary geometry  
description in plane PHIBD(L); NPHI>0  
(YB(1,L) = 0.0)

ZIDEAL      z, Compressibility factor (Ideal gas)      (1.0)

## 10.2 GLOSSARY OF OUTPUT VARIABLES

AG	$ g  =  \partial \zeta / \partial z $
AL(L)	$a(\phi)$ , Stretching parameter
AMSH	Mach number downstream of normal shock
CIS1	$\tilde{C} = \cos(-\omega)$
CIS2	$\tilde{S} = \sin(-\omega)$
DELTA	Shock layer thickness at the centerline
DH	$(H-H_0)/H_0$ , Variation of total enthalpy
DYDPH	$\partial y_b / \partial \phi$ , Circumferential body surface derivative in physical space
DYDX	$\partial y_b / \partial x$ , Longitudinal body surface derivative in physical space
ETA	$\eta$ , Ordinate in transformed space
ETAB	$b(\xi, \theta)$ , Body surface in transformed space
ETABTH	$\partial b / \partial \theta$ , Circumferential body surface derivative in transformed space
ETABXI	$\partial b / \partial \xi$ , Longitudinal body surface derivative in transformed space
ETAS	$c(\xi, \theta, \tau)$ , Bow shock surface in transformed space
ETAST	$\partial c / \partial \tau$ , Shock velocity in transformed space

ETASTH	$\partial c / \partial \theta$ , Circumferential shock surface derivative in transformed space
ETASXI	$\partial c / \partial \xi$ , Longitudinal shock surface derivative in transformed space
ETSOGM	Maximum absolute value of ETSTOG at all shock points at a given time step
ETSTOG	$ \frac{1}{g} (\partial c / \partial \tau)$ , Shock velocity in physical space
G	$\gamma$ , Isentropic exponent
H	h, Static enthalpy
H(I,J,L)	$h_{i,j,k}$ , Image of <u>i</u> th hinge point after (j-1) <u>th</u> transformation in <u>l</u> th $\phi$ plane
HTOT	$H_0$ , Freestream total enthalpy
IMG	$Im(g)$
IMGPHI	$Im(g_\phi)$
IMZETPHI	$Im(\zeta_\phi)$
M	$M_\infty$ , Freestream Mach number
MACH	M, Local Mach number
P	p, Static pressure
PHI	$\phi$ , Circumferential coordinate in physical space

PHI1	$\text{Re}(\phi)$
PHI2	$\text{Im}(\phi)$
POWER(J,L)	$\delta_{j,l}$ , Exponent of <u>j</u> th transformation in <u>l</u> th $\phi$ plane
PSH	Static pressure downstream of normal shock (Real gas, lbf/ft <sup>2</sup> )
PSTAG	$p_0$ , Stagnation pressure (Real gas, lbf/ft <sup>2</sup> )
Q	$V_\infty$ , Freestream velocity (Real gas, ft/sec)
QQ	$\frac{1}{2}\rho_\infty V_\infty^2$ , Freestream dynamic pressure (Real gas, lbf/ft <sup>2</sup> )
REG	$\text{Re}(g)$
REGPHI	$\text{Re}(g_\phi)$
REZETPHI	$\text{Re}(\zeta_\phi)$
RHO	$\rho$ , Density (Real gas, slugs/ft <sup>3</sup> )
SR	$s/R$ , Non-dimensional entropy
SRSH	Non-dimensional entropy behind normal shock
T	$T$ , Static temperature (Real gas, °R)
THETA	$\theta$ , Circumferential coordinate in transformed space
TIME	$t$ , Time coordinate

U	u, $\xi$ -velocity component
V	v, $\eta$ -velocity component
W	w, $\theta$ -velocity component
WRMS	Root-mean-square of shock velocities in physical space
X	x, Axial coordinate in physical space
XI	$\xi$ , Abscissa in transformed space
XIB	$\xi$ at body point
XIL(L)	$\xi_L(\theta)$ , Downstream boundary of computational space
XILTH(L)	$d\xi_L(\theta)/d\theta$
XIS	$\xi$ at bow shock point
XB	x at body point
Y	y, Radial coordinate in physical space
YB	y at body point
YS	y at bow shock point

### 10.3 GLOSSARY OF SUBROUTINE NAMES

Routines indicated by (\*) were obtained from the flow field code described in References 2 and 3.

AIR*	Tables of equilibrium air thermodynamic properties
ATERR	Prints out error message
ATMP*	Determination of freestream pressure and temperature from tables of 1962 Standard Atmosphere
BFL3CM	Binary file routine
BFR3CM	Reads binary file (entry point in BFL3CM)
BFW3CM	Writes binary file (entry point in BFL3CM)
CM3DT	Main routine; initialization
CM3ST	Calculates starting line data for afterbody computation
CUFT1* CUFT2* }	Cubic spline fit routines
FREE*	Calculates freestream conditions
GEOM3	Analytic body geometry subroutine
GEOM4	Initialization for arbitrary body geometry definition, with no centerline offset
GEOM4B	Arbitrary body geometry routine with no centerline offset (entry point in GEOM4)

GEOM5	Initialization for arbitrary body geometry definition, with centerline offset
GEOM5B	Arbitrary body geometry routine with centerline offset (entry point in GEOM5)
GRID3D	Calculates coordinate transformation parameters at grid points
HING3D	Calculates hinge point locations and transformations of hinge points
IDEAL*	Calculates ideal gas properties
LINB*	Solves system of linear equations (used in spline fit)
MAP3D	Conformal mapping transformation function (complex)
OUT3D	Output routine
PVE3DNC	Time-dependent calculations in non-conservation form
PVE3DL	Time-dependent calculations with the $\lambda$ -differencing scheme
REALP	Determines real part of a complex number (used in CM3ST)
RGAS <sup>+</sup>	Calculates real gas properties
RLERR	Prints out error message if range of real gas tables is exceeded

-----  
<sup>+</sup> This routine is the same as the REAL routine in Reference 3: the name has been changed to allow use of the intrinsic function REAL in complex arithmetic with CM3DT.

SHKTAB*	Constructs shock tables
SHOCK*	Calculates properties downstream of shock for specified normal freestream velocity component
STAGPT*	Calculates stagnation point conditions
TBL*	Table search
TBL1*	Single table look-up
TLU1*	Table look-up (used in spline fit)



#### 10.4 SUMMARY OF COORDINATE TRANSFORMATIONS

To provide maximum flexibility to the user, the CM3DT nosetip flow field code has been formulated to allow definition of the nosetip geometry in a coordinate system that is convenient to the user and is not necessarily aligned with the vehicle afterbody coordinate system. In addition, provision has been made for a bent afterbody axis to further generalize the applicability of the CM3DT code. This section details the relationships between the various coordinate systems that are used in the CM3DT code.

The afterbody cylindrical coordinate system,  $(r, \theta, z)$ , is defined as shown in Figure 10.1, where the axis may be bent in the pitch plane by an angle  $\delta_A$  at  $z = \bar{z}$ . Defining an afterbody Cartesian frame  $(x_1, y_1, z_1)$  oriented with the unbent afterbody axis, the Cartesian coordinates may be expressed as

$$x_1 = z - \bar{z} \quad (10.1)$$

$$y_1 = r \cos \theta + d(z) \quad (10.2)$$

$$z_1 = r \sin \theta \quad (10.3)$$

where

$$d(z) = (\bar{z} - z) \tan \delta_A \quad (10.4)$$

Another Cartesian coordinate system  $(x', y', z')$  may be defined that is oriented with the bent afterbody axis. This system is related to the  $(x_1, y_1, z_1)$  frame by

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos \delta_A & -\sin \delta_A & 0 \\ \sin \delta_A & \cos \delta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ z_1 \end{bmatrix} \quad (10.5)$$

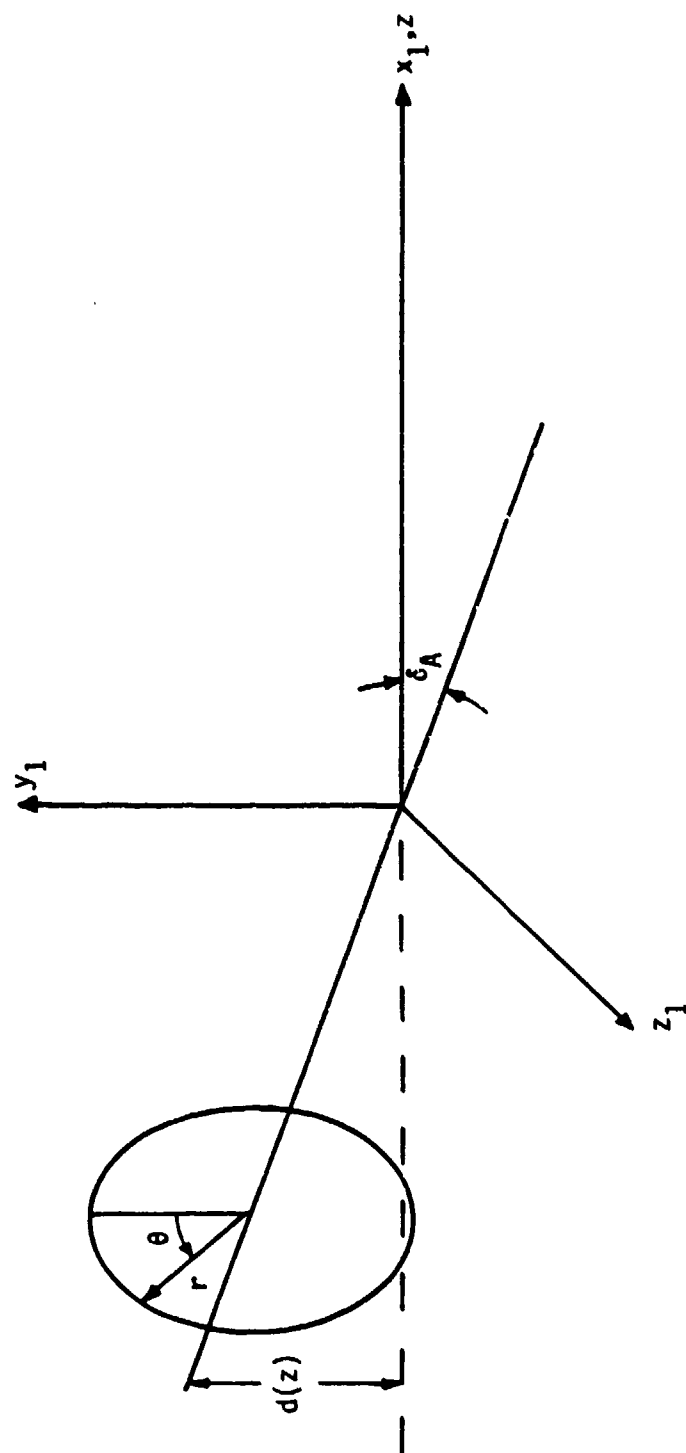


FIGURE 10.1.1. AFTERBODY COORDINATE SYSTEM

The next coordinate system of interest is the nosetip geometric cylindrical system  $(\hat{x}, \hat{y}, \hat{\phi})$ , in which the nosetip geometry is to be defined in CM3DT. The associated Cartesian system, denoted by  $(\hat{x}_c, \hat{y}_c, \hat{z}_c)$ , is defined from

$$\hat{x}_c = \hat{x} \quad (10.6)$$

$$\hat{y}_c = \hat{y} \cos \hat{\phi} \quad (10.7)$$

$$\hat{z}_c = \hat{y} \sin \hat{\phi} \quad (10.8)$$

As discussed in Section 4 of this report, the nosetip geometric axis intersects the bent afterbody axis at  $z = z_0$  and  $\hat{x} = \hat{x}_0$ , and may be rotated in both pitch and yaw by the angles  $\delta_1$  and  $\delta_2$ , respectively, as shown in Figure 10.2. The  $(\hat{x}_c, \hat{y}_c, \hat{z}_c)$  and  $(x', y', z')$  Cartesian systems may then be related through

$$\begin{Bmatrix} \hat{x}_c - \hat{x}_0 \\ \hat{y}_c \\ \hat{z}_c \end{Bmatrix} = \begin{bmatrix} \cos \delta_1 & -\sin \delta_1 & 0 \\ \sin \delta_1 & \cos \delta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos \delta_2 & 0 & -\sin \delta_2 \\ 0 & 1 & 0 \\ \sin \delta_2 & 0 & \cos \delta_2 \end{bmatrix} \begin{Bmatrix} x' + (\bar{z} - z_0)/\cos \delta_A \\ y' \\ z' \end{Bmatrix} \quad (10.9)$$

The  $(\hat{x}, \hat{y}, \hat{\phi})$  nosetip geometric coordinate system also serves as the  $(x, y, \phi)$  computational coordinate system in the CM3DT code for those cases where there is no offset to the cross-section centers (NSEG>0 or NPFI>0). However, if the cross-section centers are offset (NPFI<0) the computational axis will not be coincident with the geometric axis, and additional transformations will be required.

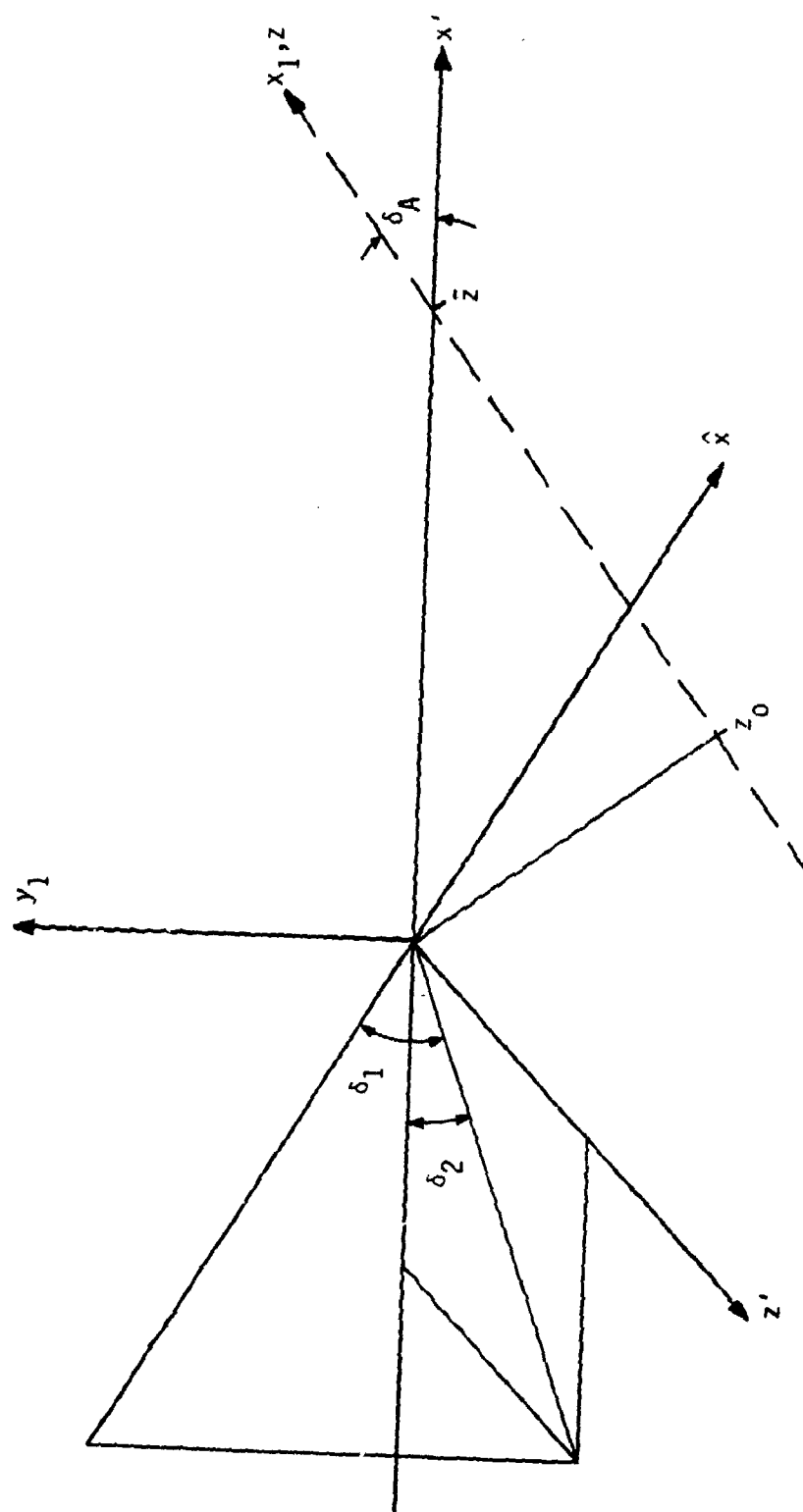


FIGURE 10.2. NOSETIP GEOMETRIC COORDINATE SYSTEM ORIENTATION

The nosetip computational axis is defined as a straight line that passes through the points  $(\hat{x}_{b0}, d_{10}, d_{20})$ ,  $(\hat{x}_0, 0, 0)$  in the geometric Cartesian coordinate system, where  $\hat{x}_{b0} = XB0$ ,  $d_{10} = D1(1)$ ,  $d_{20} = D2(1)$ , and  $\hat{x}_0 = XH0$ . As shown in Figure 10.3, the orientation of the computational axis to the geometric axis can be described by the angles  $\delta_{1N}$  and  $\delta_{2N}$ :

$$\tan \delta_{2N} = d_{20} / (\hat{x}_0 - \hat{x}_{b0}) \quad (10.10)$$

$$\tan \delta_{1N} = d_{10} \cos \delta_{2N} / (\hat{x}_0 - \hat{x}_{b0}) \quad (10.11)$$

Defining the Cartesian frame oriented with the computational axis as  $(x_c, y_c, z_c)$ , the transformation to the computational frame becomes

$$\begin{Bmatrix} x_c - (\hat{x}_0 - \hat{x}_{b0}) / (\cos \delta_{1N} \cos \delta_{2N}) \\ y_c \\ z_c \end{Bmatrix} = \begin{bmatrix} \cos \delta_{1N} & -\sin \delta_{1N} & 0 \\ \sin \delta_{1N} & \cos \delta_{2N} & 0 \\ 0 & 0 & 1 \end{bmatrix} \mathbf{x}$$

$$\begin{bmatrix} \cos \delta_{2N} & 0 & -\sin \delta_{2N} \\ 0 & 1 & 0 \\ \sin \delta_{2N} & 0 & \cos \delta_{2N} \end{bmatrix} \begin{Bmatrix} \hat{x}_c - \hat{x}_0 \\ \hat{y}_c \\ \hat{z}_c \end{Bmatrix} \quad (10.12)$$

This transformation is defined such that the most forward body point in the geometric system,  $\hat{x} = \hat{x}_{b0}$ , has the value  $x_c = 0$  in the computational system. The CM3DT code automatically redefines the input parameters  $XB0$  and  $XH0$  to be 0 and  $(\hat{x}_0 - \hat{x}_{b0}) / \cos \delta_{1N} \cos \delta_{2N}$ , respectively, when a new computational axis is defined. In addition, the code also redefines the angles  $\delta_1$  and  $\delta_2$  so that they represent the orientation of the computational axis to the bent afterbody axis.



FIGURE 10.3. NOSETIP COMPUTATIONAL COORDINATE SYSTEM ORIENTATION

The redefinition of  $\delta_1$  and  $\delta_2$  is accomplished by expressing the coordinates of the point  $(\hat{x}_{b0}, d_{10}, d_{20})$  in the geometric coordinate system in terms of the Cartesian system oriented with the bent afterbody axis (by inversion of Equation (10.9)) to yield

$$\begin{Bmatrix} x' + (\bar{z} - z_0)/\cos \delta_A \\ y' \\ z' \end{Bmatrix} = \begin{bmatrix} \cos \delta_2 & 0 & \sin \delta_2 \\ 0 & 1 & 0 \\ -\sin \delta_2 & 0 & \cos \delta_2 \end{bmatrix} \begin{matrix} x \\ y \\ z \end{matrix}$$

$$\begin{bmatrix} \cos \delta_1 & \sin \delta_1 & 0 \\ -\sin \delta_1 & \cos \delta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} \hat{x}_{b0} - \hat{x}_0 \\ d_{10} \\ d_{20} \end{Bmatrix} \quad (10.13)$$

(Note that in Equation (10.13) the angles  $\delta_1$  and  $\delta_2$  are the values input by the user to define the orientation of the geometric axis.)

New values of  $\delta_1$  and  $\delta_2$  (defining the orientation of the computational axis) can be determined from the results of Equation (10.13) as

$$\tan \delta_2 = -z' / \{x' - (\bar{z} - z_0)/\cos \delta_A\} \quad (10.14)$$

$$\tan \delta_1 = -y' \cos \delta_2 / \{x' - (\bar{z} - z_0)/\cos \delta_A\} \quad (10.15)$$

## 10.5 SAMPLE CM3DT OUTPUT

- a.) SAMPLE CASE 1. TITLE SHEET.
- b.) SAMPLE CASE 2. TITLE SHEET.
- c.) SAMPLE CASE 3. TITLE SHEET.
- d.) SAMPLE CASE 3 (AFTERBODY). TITLE SHEET.
- e.) ANALYTIC GEOMETRY INPUT (SAMPLE CASE 1).
- f.) ARBITRARY GEOMETRY INPUT (NPHI = 1) (SAMPLE CASE 2).
- g.) ARBITRARY GEOMETRY INPUT (NPHI = 2) (SAMPLE CASE 3).
- h.) HINGE POINT TRANSFORMATION (SAMPLE CASE 3).
- i.) CIRCUMFERENTIAL TRANSFORMATION DATA (SAMPLE CASE 3).
- j.) BODY GEOMETRY INFORMATION (SAMPLE CASE 2).
- k.) SAMPLE TIME HISTORY OUTPUT (SAMPLE CASE 1).
- l.) FIELD OUTPUT (SAMPLE CASE 1).
- m.) FIELD OUTPUT (SAMPLE CASE 2).
- n.) FIELD OUTPUT (SAMPLE CASE 3).
- o.) FIELD OUTPUT, JOUT = 1 (SAMPLE CASE 3).
- p.) FIELD OUTPUT, JOUT = 2 (SAMPLE CASE 3).



CH3DT(MC) SPHERE MACH 20 ALPHA=5 BETA=5  
THREE DIMENSIONAL BLUNT BODY LOPE  
CONFORMAL MAPPING COORDINATE TRANSFORMATION

P S/R H Q RHO I Z C  
1.00000E+00 0. 3.50000E+00 2.36643E+01 2.00000E+01 1.00000E+00 1.00000E+00 1.00000E+00 1.00000E+00 2.00000E+02  
RIDEAL ZIDEAL CIDEAL P0 IDEAL GAS CO PREF IREF SREF  
1.0000E+00 1.0000E+00 1.4000E+00 0. 2.5031E+04 1.0000E+00 1.0000E+00 1.0000E+00 1.0000E+00 0.

ALPHA= 5.000 BETA= 5.000  
ORIENTATION OF MOSFIT GEOMETRIC AXIS RELATIVE TO BEMT AFTERBODY AXIS DEL1= 0.000 DEL2= 0.000  
BEND ANGLE OF AFTERBODY AXIS DELA= 0.000  
PITCH AND YAW RELATIVE TO MOSFIT GEOMETRIC AXIS ALPHA= 5.000 BETA= 5.000

ISA= 2  
MMAI= 6 MMAX=10 LMAX= 8  
KMAI= 300 KSTART= -1 KGRID= 10 KIAPE= -1  
KOUT=300 JOUT= 0

NUMBER OF HINGE POINTS (JC)= 7  
NUMBER OF CORNERS (JA)= 5  
IMINCE= 0 INAP= 0 DFLH= .100

XBO= 0.0000 XMO= 0.0000 RM= .5000  
XBB= .5000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000  
TEST= 1.0000E-06 1.0000E-06 1.0000E-06 0. 0. 0. 0. 0. 0. 1.5000E+00  
0. 0. 1.0000E-06 1.0000E-06 0. 0. 0. 0. 0. 0.

PSIAG= 5.1548E+02 HTOT= 2.8350E+02 PSN= 4.6650E+02 SRSH= 9.1355E+00 AMSH= 3.8035E-01

NON-CONSERVATION EQUATIONS ARE SOLVED

NO PLANE OF SYMMETRY

IDEAL GAS THERMODYNAMICS

AXISYMMETRIC CONFORMAL MAPPING

HINGE POINTS GENERATED AUTOMATICALLY

a.) SAMPLE CASE 1. TITLE SHEET

THREE DIMENSIONAL BLUNT BODY CODE  
CONFORMAL MAPPING COORDINATE TRANSFORMATION

NUMBER OF HINGE POINTS (JC)= 9  
NUMBER OF CORNERS (JA)= 7  
HINGE= 0 INAP= 0

```
ISQ= 0.000 XHQ= 0.  
ICB= 6.000  
  
TEST= 1.000E-06 1.000E-  
0.  
  
RMS= 1.750  
TEND 6.000
```

-----  
 ..TOT= 0.7402E+01  
 PSH= 1.5682E+02  
 SRSN= 6.4947E+00  
 ANSH= 3.8513E-01

# NUM-CONSERVATION EQUATIONS SOLVED WITH LAMBDA DIFFRENCING SCHEME

# PITCH PLANE OF SYMMETRY ASSUMED

# LOCAL GAS THERMODYNAMICS

## AXISYNTHETIC CONFORMAL MAPPING

# HINCE POINTS GENERATED AUTOMATICALLY

**b.) SAMPLE CASE 2. TITLE SHEET**

### THREE DIMENSIONAL PLUNT BODY CONE CONFORMAL MAPPING COORDINATE TRANSFORMATION

P	S/K	FREE STREAM CONDITIONS							
		H	G	M	RHO	I	Z	E	WU
1.00000E+00	0.	3.5000E+00	1.50551E+01	1.3400E+01	1.0700E+00	1.0000F+00	1.0000E+00	1.0000E+00	1.25632E+02
						IDEAL GAS			
			JAC = 0	P0	H0	C0	VREF	IREF	JAREF
			RRFAL				1.0000E+00	1.0000E+00	0.
		ZIDFAL	GINFAL						
		1.0000E+00	1.4000E+00						
		RIDFAL							
		1.0000E+00							

ALPHA= 3.000      BETA= 0.000  
ORIENTATION OF MOSIIP GEOMETRIC AXIS RELATIVE TO REM: AFTERBODY AXIS      DELTA= 9.648      DELT2= 0.000  
BEND ANGLE OF AFTERBODY AXIS      DELTA= 0.000  
BEND ANGLE AND YAW RELATIVE TO MOSIIP GEOMETRIC AXIS      ALPHA= 12.643      BETA= 0.000

```
ISA= 1      MMAX= 6      LMAX= 9
KMAX= 500   KSTART= -1   KEND= 1
KOUT=500    JOUT= 2
```

```

NUMBER OF HINGE POINTS (JC)= 4
NUMBER OF CURVES (JA)= 7
HINGE= 4      INAF= 1      DELM= .150

```

```

XBO= .2200 XMO= 0.0000 RM= 1. -00
XB= 2.4000 2.8000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
TEST= 1.0000E-06 1.0000E-06 1.0000E-06 0. 0. 0. 0. 0. 0. 1.5000E+00

```

PSTAC= 2.3165E+02 HIOT= 1.2449E+02 PSH= 2.0912E+02 SRSN= 7.01846E+00 ANSH= 3.08334E-01

# NOW CONSERVATION EQUATIONS SOLVED WITH LAMBDA DIFFERENCING SCHEME

### FITCH PLANE OF SYMMETRY ASSUMED

## IDEAL GAS THERMODYNAMICS

# NON-SYMMETRIC CONFORMAL MAPPING

# HINGE POINTS GENERATED AUTOMATICALLY

**C.) SAMPLE CASE 3. TITLE SHEET**



CROSS-SECTION				BODY GEOMETRY			
	MBJ	IBJ	IEC1	EC1	IEC2	EC2	
1	1	1	0	0.	0	0.	
2	1	1	0	0.	0	0.	
CROSS-SECTION 1							
Y				X	Y		
	-1.3408E+00						
							Z = 1.2757E+01
							A
							Y
CROSS-SECTION 2							
Y				X	Y		
	-4.9460E+00						
							Z = 4.7000E+01
							A
							Y

d.(cont'd.) SAMPLE CASE 3 (AFTERBODY). GEOMETRIC INPUT

ANALYTIC BODY GEOMETRY  
ASYMPTOTIC CONFIGURATION

ACOF(I,J)	
1	0.000000
2	0.000000
3	0.000000
4	0.000000
5	0.000000
6	0.000000
7	0.000000
8	0.000000
9	1.000000
10	-5.000000
11	-5.000000
12	0.000000

e.) ANALYTIC GEOMETRY INPUT (SAMPLE CASE 1).

ARBITRARY BODY GEOMETRY OPTION USED WITHOUT OFFSET CENTERLINE  
 AXISYMMETRIC GEOMETRY  
 CIRCULAR CROSS-SECTIONS CENTERED ON X-AXIS  
 PLANE 1 PHI=180.00

I	XB(I,L)	YB(I,L)
1	0.00000	0.00000
2	.00650	.15110
3	.02690	.30590
4	.06170	.46060
5	.10960	.60970
6	.17010	.75100
7	.26720	.87900
8	.42180	.98030
9	.61130	1.07270
10	.81540	1.17220
11	1.03820	1.27090
12	1.29120	1.40430
13	1.56920	1.55110
14	1.85620	1.72990
15	2.13950	1.94200
16	2.41220	2.18180
17	2.65640	2.43180
18	2.89480	2.67660
19	3.12550	2.90760
20	3.36840	3.09840
21	3.65520	3.26450
22	4.00000	3.39850
23	4.20000	3.48830
24	4.40000	3.67930
25	4.60000	3.50040
26	4.80000	3.52160
27	5.00000	3.54240
28	5.50000	3.59500
29	6.00000	3.64750
30	6.50000	3.70010

f.) ARBITRARY GEOMETRY INPUT (NPHI = 1) (SAMPLE CASE 2).

ARBITRARY BODY GEOMETRY OPTION USED WITHOUT OFFSET CENTRAL LINE  
CIRCULAR CROSS-SECTIONS OFFSET FROM X-AXIS

PLANE 1 PHI= 0.00

1 X(C,L) Y(C,L)

1	.2200	0.0000
2	.2300	.2000
3	.2470	.3000
4	.2800	.4000
5	.3000	.4300
6	.7400	.5000
7	.4000	.5700
8	.4270	.6000
9	.5000	.6670
10	.7000	.8100
11	.8000	.8450
12	.9000	.9200
13	1.0000	1.0000
14	1.1000	1.0000
15	1.1600	1.0220
16	1.2000	1.0380
17	1.2200	1.0430
18	1.2400	1.0500
19	1.2800	1.0600
20	1.4000	1.0950
21	1.6000	1.1500
22	1.8000	1.2000
23	2.0000	1.2450
24	2.2000	1.3710
25	2.4000	1.3770
26	2.6000	1.4330
27	3.0000	1.4800
28	3.0000	1.5450

PLANE 2 PHI=180.00

1 X(C,L) Y(C,L)

1	.2200	0.0000
2	.2300	.0400
3	.2450	.1000
4	.2600	.1600
5	.3000	.2450
6	.3400	.3020
7	.3800	.3450
8	.4200	.3780
9	.4600	.4120
10	.6000	.5270
11	.8000	.6950
12	1.0000	.8600
13	1.2000	1.0270
14	1.4000	1.1950
15	1.6000	1.2300
16	1.8000	1.2600
17	1.5700	1.3000
18	1.5600	1.3200
19	1.6000	1.3470
20	1.6500	1.3630
21	1.7000	1.3750
22	1.7400	1.3800
23	1.8000	1.3770
24	1.9000	1.3720
25	2.0000	1.3650
26	2.2000	1.3520
27	2.4000	1.3390
28	2.6000	1.3270
29	2.8000	1.3140
30		1.3010

9.) ARBITRARY GEOMETRY INPUT (NPHI = 2) (SAMPLE CASE 3).



# TRANSFORMATION OF HINGE POINTS

[illegible][illegible]

8 ( -2.4508, .00000, -2.1377, .00000, -2.1379, .00000, -1.6516, .00000, .00000)  
 9 ( 1.6407, .00000, .00000, .00000, .00000, .00000, .00000, .00000, .00000)  
 10 ( 1.1643, .00000, .00000, .00000, .00000, .00000, .00000, .00000, .00000)  
 11 ( 1.9946, .00000, .00000, .00000, .00000, .00000, .00000, .00000, .00000)  
 12 ( 1.1588, .00000, .00000, .00000, .00000, .00000, .00000, .00000, .00000)  
 13 ( 1.9851, .00000, .00000, .00000, .00000, .00000, .00000, .00000, .00000)

L= 3 THETA= 45.000

J POWER(J,L) M(I,J,L)  
 1 1.7397 .0198, .3700, 0.0000, .4523, .3033, .7764, .6478, 1.2480  
 2 .8020 .8389, 1.1783, .0618, 1.0013, .0023, 1.0453, 2.5356, 1.2480  
 3 .8457 .5716, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 4 .9404 .0146, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 5 .9574 .6112, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 6 .9840 .1214, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 7 .9942 .1838, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 8 .24710, .0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 9 .0000, .0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 10 .0000, .0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000

L= 4 THETA= 67.500

J POWER(J,L) M(I,J,L)  
 1 1.6913 .0198, .3700, 0.0000, .4754, .3576, .0169, .0000, 1.2431  
 2 .8093 .8305, 1.2239, .0772, 1.6455, 1.0630, 2.0978, 2.5752, 1.2431  
 3 .9170 .5646, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 4 .9501 .0111, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 5 .9306 .6522, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 6 .9808 .12012, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000  
 7 .9938 .1828, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000

h. (cont'd.) HINGE POINT TRANSFORMATION  
 (SAMPLE CASE 3).

CIRCUMFERENTIAL PLANES						
L	THETA	XBR	XIL	XILH	AL	
1	0.00000	2.40000	1.81527	.00000	1.00000	
2	.39270	2.45000	1.81922	-.00737	.99522	
3	.78540	2.50000	1.80519	-.04749	.98591	
4	1.17810	2.55000	1.76501	-.06408	.97592	
5	1.57080	2.60000	1.75677	-.06612	.96193	
6	1.96350	2.65000	1.73718	-.03681	.95077	
7	2.35619	2.70000	1.72694	-.01452	.94208	
8	2.74889	2.75000	1.72774	.02281	.93708	
9	3.14159	2.80000	1.73698	.00000	.93508	

i.) CIRCUMFERENTIAL TRANSFORMATION DATA (SAMPLE CASE 3).

# BODY GEOMETRY INFORMATION

L= 1 THEIA= 0.00

M	XB	YB	DYDX	DYDPH	XIB	EIAR	ETABXI	FIABTH
1	-0.000	0.000	0.000	0.000	0.000	.1827	-0.000	0.000
2	.0124	.0000	0.000	0.000	.1777	.1973	.1426	0.000
3	.0683	0.000	0.000	0.000	.3553	.2139	.1127	0.000
4	.1704	.7516	1.9743	0.000	.5330	.2221	-0.006	0.000
5	.5821	.5591	.8400	0.000	.7107	.1756	.1756	0.000
6	.6543	1.0934	.4840	0.000	.8884	.1130	-0.192	0.000
7	.5789	1.2482	.4867	0.000	1.0660	.0887	-0.1124	0.000
8	1.3574	1.4376	.5083	0.000	1.2437	.0690	-0.1035	0.000
9	1.7889	1.6861	.6579	0.000	1.4214	.0534	-0.0796	0.000
10	2.2822	1.9935	.8369	0.000	1.5990	.0461	.0067	0.000
11	2.5796	2.3580	1.0337	0.000	1.7767	.0572	.1022	0.000
12	2.9376	2.7211	1.0392	0.000	1.9544	.0751	.1064	0.000
13	3.2986	3.0492	.7334	0.000	2.1321	.0854	-0.0125	0.000
14	3.6811	3.2769	.4705	0.000	2.3097	.0846	.0373	0.000
15	4.1497	3.4777	.2242	0.000	2.4874	.0836	-0.0800	0.000
16	4.7023	3.5110	.1057	0.000	2.6651	.0592	-0.1183	0.000
17	5.3082	3.5748	.1054	0.000	2.8427	.0482	-0.0359	0.000
18	6.0000	3.6475	.1050	0.000	3.0204	.0427	-0.0247	0.000

L= 2 THEIA= 22.50

M	XB	YB	DYDX	DYDPH	XIB	EIAR	ETABXI	FIABTH
1	-0.000	0.000	0.000	0.000	0.000	.1827	-0.000	0.000
2	.0124	.0000	0.000	0.000	.1777	.1973	.1426	0.000
3	.0683	0.000	0.000	0.000	.3553	.2139	.1127	0.000
4	.1704	.7516	1.9743	0.000	.5330	.2221	-0.006	0.000
5	.5821	.5591	.8400	0.000	.7107	.1756	.1756	0.000
6	.6543	1.0934	.4840	0.000	.8884	.1130	-0.192	0.000
7	.5789	1.2482	.4867	0.000	1.0660	.0887	-0.1124	0.000
8	1.3574	1.4376	.5083	0.000	1.2437	.0690	-0.1035	0.000
9	1.7889	1.6861	.6579	0.000	1.4214	.0534	-0.0796	0.000
10	2.2822	1.9935	.8369	0.000	1.5990	.0461	.0067	0.000
11	2.5796	2.3580	1.0337	0.000	1.7767	.0572	.1022	0.000
12	2.9376	2.7211	1.0392	0.000	1.9544	.0751	.1064	0.000
13	3.2986	3.0492	.7334	0.000	2.1321	.0854	-0.0125	0.000
14	3.6811	3.2769	.4705	0.000	2.3097	.0846	.0373	0.000
15	4.1497	3.4777	.2242	0.000	2.4874	.0836	-0.0800	0.000
16	4.7023	3.5110	.1057	0.000	2.6651	.0592	-0.1183	0.000
17	5.3082	3.5748	.1054	0.000	2.8427	.0482	-0.0359	0.000
18	6.0000	3.6475	.1050	0.000	3.0204	.0427	-0.0247	0.000

L= 3 THEIA= 45.00

M	XB	YB	DYDX	DYDPH	XIB	EIAR	ETABXI	FIABTH
1	-0.000	0.000	0.000	0.000	0.000	.1827	-0.000	0.000
2	.0124	.0000	0.000	0.000	.1777	.1973	.1426	0.000
3	.0683	0.000	0.000	0.000	.3553	.2139	.1127	0.000
4	.1704	.7516	1.9743	0.000	.5330	.2221	-0.006	0.000
5	.5821	.5591	.8400	0.000	.7107	.1756	.1756	0.000
6	.6543	1.0934	.4840	0.000	.8884	.1130	-0.192	0.000
7	.5789	1.2482	.4867	0.000	1.0660	.0887	-0.1124	0.000
8	1.3574	1.4376	.5083	0.000	1.2437	.0690	-0.1035	0.000
9	1.7889	1.6861	.6579	0.000	1.4214	.0534	-0.0796	0.000
10	2.2822	1.9935	.8369	0.000	1.5990	.0461	.0067	0.000
11	2.5796	2.3580	1.0337	0.000	1.7767	.0572	.1022	0.000
12	2.9376	2.7211	1.0392	0.000	1.9544	.0751	.1064	0.000
13	3.2986	3.0492	.7334	0.000	2.1321	.0854	-0.0125	0.000
14	3.6811	3.2769	.4705	0.000	2.3097	.0846	.0373	0.000
15	4.1497	3.4777	.2242	0.000	2.4874	.0836	-0.0800	0.000
16	4.7023	3.5110	.1057	0.000	2.6651	.0592	-0.1183	0.000
17	5.3082	3.5748	.1054	0.000	2.8427	.0482	-0.0359	0.000
18	6.0000	3.6475	.1050	0.000	3.0204	.0427	-0.0247	0.000

L= 4 THEIA= 67.50

M	XB	YB	DYDX	DYDPH	XIB	EIAR	ETABXI	FIABTH
1	-0.000	0.000	0.000	0.000	0.000	.1827	-0.000	0.000
2	.0124	.0000	0.000	0.000	.1777	.1973	.1426	0.000
3	.0683	0.000	0.000	0.000	.3553	.2139	.1127	0.000
4	.1704	.7516	1.9743	0.000	.5330	.2221	-0.006	0.000
5	.5821	.5591	.8400	0.000	.7107	.1756	.1756	0.000
6	.6543	1.0934	.4840	0.000	.8884	.1130	-0.192	0.000
7	.5789	1.2482	.4867	0.000	1.0660	.0887	-0.1124	0.000
8	1.3574	1.4376	.5083	0.000	1.2437	.0690	-0.1035	0.000
9	1.7889	1.6861	.6579	0.000	1.4214	.0534	-0.0796	0.000
10	2.2822	1.9935	.8369	0.000	1.5990	.0461	.0067	0.000
11	2.5796	2.3580	1.0337	0.000	1.7767	.0572	.1022	0.000
12	2.9376	2.7211	1.0392	0.000	1.9544	.0751	.1064	0.000
13	3.2986	3.0492	.7334	0.000	2.1321	.0854	-0.0125	0.000
14	3.6811	3.2769	.4705	0.000	2.3097	.0846	.0373	0.000
15	4.1497	3.4777	.2242	0.000	2.4874	.0836	-0.0800	0.000
16	4.7023	3.5110	.1057	0.000	2.6651	.0592	-0.1183	0.000
17	5.3082	3.5748	.1054	0.000	2.8427	.0482	-0.0359	0.000
18	6.0000	3.6475	.1050	0.000	3.0204	.0427	-0.0247	0.000

j.) BODY GEOMETRY INFORMATION (SAMPLE CASE 2).

K= 1	TIME=	1.00000E-00	PSTAG=	5.15485E+02	DELIA=	6.57690E-02	WRMS=	7.28885E-00	ETSOLM=	7.00125E-00
K= 2	TIME=	5.13924E-04	PSTAG=	5.63921E+02	DELIA=	6.57690E-02	WRMS=	1.15255E-01	ETSOLM=	3.51043E-01
K= 3	TIME=	1.02784E-03	PSTAG=	5.95216E+02	DELIA=	6.57690E-02	WRMS=	2.15300E-01	ETSOLM=	6.52613E-01
K= 4	TIME=	1.54718E-03	PSTAG=	6.11287E+02	DELIA=	6.57690E-02	WRMS=	3.01230E-01	ETSOLM=	9.00930E-01
K= 5	TIME=	2.05670E-03	PSTAG=	6.12508E+02	DELIA=	6.57690E-02	WRMS=	3.73639E-01	ETSOLM=	1.11172E+00
K= 6	TIME=	2.56980E-03	PSTAG=	6.02047E+02	DELIA=	6.57690E-02	WRMS=	4.34009E-01	ETSOLM=	1.26674E+00
K= 7	TIME=	3.08394E-03	PSTAG=	5.81960E+02	DELIA=	6.57690E-02	WRMS=	4.82501E-01	ETSOLM=	1.41764E+00
K= 8	TIME=	3.59819E-03	PSTAG=	5.57078E+02	DELIA=	6.57690E-02	WRMS=	5.19290E-01	ETSOLM=	1.51040E+00
K= 9	TIME=	4.11259E-03	PSTAG=	5.16277E+02	DELIA=	6.57690E-02	WRMS=	5.47611E-01	ETSOLM=	1.55678E+00
K= 10	TIME=	4.62719E-03	PSTAG=	5.00966E+02	DELIA=	6.08585E-02	WRMS=	5.54095E-01	ETSOLM=	1.57000E+00
K= 11	TIME=	5.14202E-03	PSTAG=	4.91348E+02	DELIA=	6.08585E-02	WRMS=	5.45046E-01	ETSOLM=	1.51113E+00
K= 12	TIME=	5.65724E-03	PSTAG=	4.80087E+02	DELIA=	6.08585E-02	WRMS=	5.22707E-01	ETSOLM=	1.44453E+00
K= 13	TIME=	6.17285E-03	PSTAG=	4.75711E+02	DELIA=	6.08585E-02	WRMS=	4.82110E-01	ETSOLM=	1.42508E+00
K= 14	TIME=	6.68893E-03	PSTAG=	4.78033E+02	DELIA=	6.08585E-02	WRMS=	4.27295E-01	ETSOLM=	1.07650E+00
K= 15	TIME=	7.20559E-03	PSTAG=	4.80095E+02	DELIA=	6.08585E-02	WRMS=	3.69979E-01	ETSOLM=	1.01738E+00
K= 16	TIME=	7.72297E-03	PSTAG=	4.98145E+02	DELIA=	6.08585E-02	WRMS=	3.29725E-01	ETSOLM=	9.27736E-01
K= 17	TIME=	8.24122E-03	PSTAG=	5.11815E+02	DELIA=	6.08585E-02	WRMS=	3.24254E-01	ETSOLM=	8.1447E-01
K= 18	TIME=	8.76049E-03	PSTAG=	5.24609E+02	DELIA=	6.08585E-02	WRMS=	3.51607E-01	ETSOLM=	6.91320E-01
K= 19	TIME=	9.26096E-03	PSTAG=	5.34547E+02	DELIA=	6.08585E-02	WRMS=	3.92100E-01	ETSOLM=	7.02970E-01
K= 20	TIME=	9.80280E-03	PSTAG=	5.40045E+02	DELIA=	5.79476E-02	WRMS=	4.29703E-01	ETSOLM=	7.03084E-01
K= 21	TIME=	1.03321E-02	PSTAG=	5.42743E+02	DELIA=	5.79476E-02	WRMS=	4.54500E-01	ETSOLM=	7.66955E-01
K= 22	TIME=	1.08400E-02	PSTAG=	5.41088E+02	DELIA=	5.79476E-02	WRMS=	4.00535E-01	ETSOLM=	7.75444E-01
K= 23	TIME=	1.13547E-02	PSTAG=	5.39633E+02	DELIA=	5.79476E-02	WRMS=	4.08274E-01	ETSOLM=	7.42020E-01
K= 24	TIME=	1.16699E-02	PSTAG=	5.34000E+02	DELIA=	5.79476E-02	WRMS=	4.03635E-01	ETSOLM=	6.60481E-01
K= 25	TIME=	1.23763E-02	PSTAG=	5.29314E+02	DELIA=	5.79476E-02	WRMS=	4.56510E-01	ETSOLM=	6.00644E-01
K= 26	TIME=	1.28430E-02	PSTAG=	5.24836E+02	DELIA=	5.79476E-02	WRMS=	4.69830E-01	ETSOLM=	6.48940E-01
K= 27	TIME=	1.33875E-02	PSTAG=	5.21022E+02	DELIA=	5.79476E-02	WRMS=	4.45191E-01	ETSOLM=	7.15976E-01
K= 28	TIME=	1.38895E-02	PSTAG=	5.18044E+02	DELIA=	5.79476E-02	WRMS=	4.42671E-01	ETSOLM=	7.56044E-01
K= 29	TIME=	1.43907E-02	PSTAG=	5.16084E+02	DELIA=	5.79476E-02	WRMS=	4.41700E-01	ETSOLM=	7.60170E-01
K= 30	TIME=	1.48893E-02	PSTAG=	5.14985E+02	DELIA=	6.04620E-02	WRMS=	4.41500E-01	ETSOLM=	7.60470E-01
K= 31	TIME=	1.53855E-02	PSTAG=	5.14658E+02	DELIA=	6.04620E-02	WRMS=	4.41670E-01	ETSOLM=	7.67880E-01
K= 32	TIME=	1.58772E-02	PSTAG=	5.14366E+02	DELIA=	6.04620E-02	WRMS=	4.39800E-01	ETSOLM=	8.00837E-01
K= 33	TIME=	1.63649E-02	PSTAG=	5.16045E+02	DELIA=	6.04620E-02	WRMS=	4.39104E-01	ETSOLM=	8.20154E-01
K= 34	TIME=	1.68569E-02	PSTAG=	5.16111E+02	DELIA=	6.04620E-02	WRMS=	4.39509E-01	ETSOLM=	8.55130E-01
K= 35	TIME=	1.73417E-02	PSTAG=	5.17075E+02	DELIA=	6.04620E-02	WRMS=	4.41000E-01	ETSOLM=	8.76390E-01
K= 36	TIME=	1.78275E-02	PSTAG=	5.17000E+02	DELIA=	6.04620E-02	WRMS=	4.45100E-01	ETSOLM=	8.98020E-01
K= 37	TIME=	1.83127E-02	PSTAG=	5.19375E+02	DELIA=	6.04620E-02	WRMS=	4.49047E-01	ETSOLM=	9.11938E-01
K= 38	TIME=	1.87977E-02	PSTAG=	5.20215E+02	DELIA=	6.04620E-02	WRMS=	4.52356E-01	ETSOLM=	9.26096E-01
K= 39	TIME=	1.92828E-02	PSTAG=	5.20358E+02	DELIA=	6.04620E-02	WRMS=	4.54109E-01	ETSOLM=	9.34517E-01
K= 40	TIME=	1.97684E-02	PSTAG=	5.20563E+02	DELIA=	6.04620E-02	WRMS=	4.53760E-01	ETSOLM=	9.35265E-01
K= 41	TIME=	2.02549E-02	PSTAG=	5.20213E+02	DELIA=	6.04620E-02	WRMS=	4.51234E-01	ETSOLM=	9.45117E-01
K= 42	TIME=	2.07435E-02	PSTAG=	5.19516E+02	DELIA=	6.04620E-02	WRMS=	4.44300E-01	ETSOLM=	9.40949E-01
K= 43	TIME=	2.12388E-02	PSTAG=	5.18504E+02	DELIA=	6.04620E-02	WRMS=	4.55526E-01	ETSOLM=	9.55130E-01
K= 44	TIME=	2.17261E-02	PSTAG=	5.17240E+02	DELIA=	6.04620E-02	WRMS=	4.25078E-01	ETSOLM=	9.25857E-01
K= 45	TIME=	2.22070E-02	PSTAG=	5.15796E+02	DELIA=	6.04620E-02	WRMS=	4.13509E-01	ETSOLM=	9.13360E-01
K= 46	TIME=	2.27179E-02	PSTAG=	5.14265E+02	DELIA=	6.04620E-02	WRMS=	4.01216E-01	ETSOLM=	8.91941E-01
K= 47	TIME=	2.32177E-02	PSTAG=	5.12742E+02	DELIA=	6.04620E-02	WRMS=	3.88495E-01	ETSOLM=	8.79885E-01
K= 48	TIME=	2.37192E-02	PSTAG=	5.13266E+02	DELIA=	6.04620E-02	WRMS=	3.75550E-01	ETSOLM=	8.64212E-01
K= 49	TIME=	2.42221E-02	PSTAG=	5.10094E+02	DELIA=	6.04620E-02	WRMS=	3.62513E-01	ETSOLM=	8.42827E-01
K= 50	TIME=	2.47269E-02	PSTAG=	5.09301E+02	DELIA=	6.29752E-02	WRMS=	3.49437E-01	ETSOLM=	8.20283E-01
K= 51	TIME=	2.52336E-02	PSTAG=	5.08377E+02	DELIA=	6.29752E-02	WRMS=	3.36707E-01	ETSOLM=	7.95740E-01
K= 52	TIME=	2.57448E-02	PSTAG=	5.07515E+02	DELIA=	6.29752E-02	WRMS=	3.22572E-01	ETSOLM=	7.60479E-01
K= 53	TIME=	2.62506E-02	PSTAG=	5.07710E+02	DELIA=	6.29752E-02	WRMS=	3.08113E-01	ETSOLM=	7.20208E-01
K= 54	TIME=	2.67747E-02	PSTAG=	5.07116E+02	DELIA=	6.29752E-02	WRMS=	2.95623E-01	ETSOLM=	7.05562E-01
K= 55	TIME=	2.72933E-02	PSTAG=	5.07870E+02	DELIA=	6.29752E-02	WRMS=	2.83077E-01	ETSOLM=	6.73949E-01
K= 56	TIME=	2.78163E-02	PSTAG=	5.08077E+02	DELIA=	6.29752E-02	WRMS=	2.71100E-01	ETSOLM=	6.45735E-01
K= 57	TIME=	2.83377E-02	PSTAG=	5.08359E+02	DELIA=	6.29752E-02	WRMS=	2.59820E-01	ETSOLM=	6.10051E-01
K= 58	TIME=	2.88634E-02	PSTAG=	5.08507E+02	DELIA=	6.29752E-02	WRMS=	2.48914E-01	ETSOLM=	5.91033E-01
K= 59	TIME=	2.93914E-02	PSTAG=	5.08707E+02	DELIA=	6.29752E-02	WRMS=	2.38336E-01	ETSOLM=	5.60481E-01
K= 60	TIME=	2.99217E-02	PSTAG=	5.08951E+02	DELIA=	6.29752E-02	WRMS=	2.28020E-01	ETSOLM=	5.47521E-01
K= 61	TIME=	3.04540E-02	PSTAG=	5.09303E+02	DELIA=	6.29752E-02	WRMS=	2.18000E-01	ETSOLM=	5.30000E-01
K= 62	TIME=	3.09894E-02	PSTAG=	5.08226E+02	DELIA=	6.29752E-02	WRMS=	2.08226E+02	ETSOLM=	5.07921E-01
K= 63	TIME=	3.15264E-02	PSTAG=	5.07953E+02	DELIA=	6.29752E-02	WRMS=	1.9853E+02	ETSOLM=	4.93129E-01
K= 64	TIME=	3.20647E-02	PSTAG=	5.07623E+02	DELIA=	6.29752E-02	WRMS=	1.8888E+02	ETSOLM=	4.93785E-01

k.) SAMPLE TIME HISTORY OUTPUT (SAMPLE CASE 1)

STEP 300 TIME= 1.63967E-01

PLANE 1 IMETA= 0.00

# SHOCK DATA

N	X	Y	Z	U	V	W	SR	RHO	DM	EIASI	EIASX	EIASY	EIASZ
1	-5.5649E-10	5.7700E-04	-6.6371E-07	2.6933E-06	0.	1.6234E-01	-7.838E-05	-6.5712E-05	-7.4338E-04	1.6472E-01	1.6472E-01	1.6472E-01	1.6472E-01
2	5.5649E-10	5.7700E-04	-6.6371E-07	2.6933E-06	0.	1.6234E-01	-7.838E-05	-6.5712E-05	-7.4338E-04	1.6472E-01	1.6472E-01	1.6472E-01	1.6472E-01
3	2.2732E-02	1.4905E-01	-4.5493E-02	1.6604E-01	2.6097E-01	1.6582E-01	3.9788E-04	3.4228E-04	3.3540E-02	3.3540E-02	3.3540E-02	3.3540E-02	3.3540E-02
4	5.0736E-02	2.1946E-01	-1.9137E-02	2.5223E-01	3.0145E-01	1.7015E-01	7.4678E-04	6.6255E-04	6.8040E-02	6.8040E-02	6.8040E-02	6.8040E-02	6.8040E-02
5	9.1816E-02	2.8877E-01	1.8825E-02	3.3525E-01	4.0193E-01	1.7533E-01	1.0303E-03	9.5670E-04	9.6654E-02	9.6654E-02	9.6654E-02	9.6654E-02	9.6654E-02
6	1.4443E-01	3.5157E-01	6.7719E-02	4.1792E-01	5.0242E-01	1.8433E-01	1.2034E-03	1.1002E-03	1.1002E-03	1.1002E-03	1.1002E-03	1.1002E-03	1.1002E-03
7	2.0947E-01	4.0693E-01	1.2956E-01	5.0011E-01	6.0290E-01	1.9517E-01	1.3365E-03	1.4385E-03	1.4385E-03	1.4385E-03	1.4385E-03	1.4385E-03	1.4385E-03
8	2.8950E-01	4.5353E-01	2.0556E-01	5.8341E-01	7.0538E-01	2.0902E-01	1.5101E-03	1.7653E-03	1.7653E-03	1.7653E-03	1.7653E-03	1.7653E-03	1.7653E-03
9	3.8352E-01	4.8624E-01	2.9846E-01	6.0858E-01	8.0307E-01	2.2505E-01	1.7146E-03	2.2548E-03	2.2548E-03	2.2548E-03	2.2548E-03	2.2548E-03	2.2548E-03
10	5.0000E-01	5.0000E-01	4.1093E-01	7.5667E-01	9.0435E-01	2.4200E-01	2.0514E-03	3.0654E-03	3.0654E-03	3.0654E-03	3.0654E-03	3.0654E-03	3.0654E-03

N= 1

N	X	Y	Z	U	V	W	SR	RHO	DM	EIASI	EIASX	EIASY	EIASZ
1	-5.5649E-10	5.7700E-04	-6.6371E-07	2.6933E-06	0.	1.6234E-01	-7.838E-05	-6.5712E-05	-7.4338E-04	1.6472E-01	1.6472E-01	1.6472E-01	1.6472E-01
2	5.5649E-10	5.7700E-04	-6.6371E-07	2.6933E-06	0.	1.6234E-01	-7.838E-05	-6.5712E-05	-7.4338E-04	1.6472E-01	1.6472E-01	1.6472E-01	1.6472E-01
3	2.2732E-02	1.4905E-01	-4.5493E-02	1.6604E-01	2.6097E-01	1.6582E-01	3.9788E-04	3.4228E-04	3.3540E-02	3.3540E-02	3.3540E-02	3.3540E-02	3.3540E-02
4	5.0736E-02	2.1946E-01	-1.9137E-02	2.5223E-01	3.0145E-01	1.7015E-01	7.4678E-04	6.6255E-04	6.8040E-02	6.8040E-02	6.8040E-02	6.8040E-02	6.8040E-02
5	9.1816E-02	2.8877E-01	1.8825E-02	3.3525E-01	4.0193E-01	1.7533E-01	1.0303E-03	9.5670E-04	9.6654E-02	9.6654E-02	9.6654E-02	9.6654E-02	9.6654E-02
6	1.4443E-01	3.5157E-01	6.7719E-02	4.1792E-01	5.0242E-01	1.8433E-01	1.2034E-03	1.1002E-03	1.1002E-03	1.1002E-03	1.1002E-03	1.1002E-03	1.1002E-03
7	2.0947E-01	4.0693E-01	1.2956E-01	5.0011E-01	6.0290E-01	1.9517E-01	1.3365E-03	1.4385E-03	1.4385E-03	1.4385E-03	1.4385E-03	1.4385E-03	1.4385E-03
8	2.8950E-01	4.5353E-01	2.0556E-01	5.8341E-01	7.0538E-01	2.0902E-01	1.5101E-03	1.7653E-03	1.7653E-03	1.7653E-03	1.7653E-03	1.7653E-03	1.7653E-03
9	3.8352E-01	4.8624E-01	2.9846E-01	6.0858E-01	8.0307E-01	2.2505E-01	1.7146E-03	2.2548E-03	2.2548E-03	2.2548E-03	2.2548E-03	2.2548E-03	2.2548E-03
10	5.0000E-01	5.0000E-01	4.1093E-01	7.5667E-01	9.0435E-01	2.4200E-01	2.0514E-03	3.0654E-03	3.0654E-03	3.0654E-03	3.0654E-03	3.0654E-03	3.0654E-03

N= 2

N	X	Y	Z	U	V	W	SR	RHO	DM	EIASI	EIASX	EIASY	EIASZ
1	-1.2535E-02	4.8495E-06	5.0267E-02	1.7865E-01	-7.0798E-01	1.6574E-01	9.1270E-01	0.2643E+00	2.0120E-01	1.6472E-01	1.6472E-01	1.6472E-01	1.6472E-01
2	7.1949E-03	7.6412E-02	4.7595E-02	3.5113E-01	-0.8279E-01	1.6444E-01	9.1110E-01	0.0535E+00	3.6232E-01	3.6232E-01	3.6232E-01	3.6232E-01	3.6232E-01
3	4.7823E-03	1.5275E-01	4.7524E-02	5.6729E-01	-7.4776E-01	1.4005E-01	9.0870E-01	5.4200E+00	5.7256E-01	5.7256E-01	5.7256E-01	5.7256E-01	5.7256E-01
4	3.7607E-02	2.2592E-01	3.6554E-02	7.3873E-01	-5.7328E-01	1.3603E-01	9.0454E-01	5.0952E+00	7.9699E-01	7.9699E-01	7.9699E-01	7.9699E-01	7.9699E-01
5	7.8019E-02	2.9777E-01	2.8541E-02	9.9596E-01	-7.2265E-01	1.3709E-01	9.0224E-01	4.3122E+00	1.0405E+00	1.0405E+00	1.0405E+00	1.0405E+00	1.0405E+00
6	1.3055E-01	3.6411E-01	2.0067E-02	1.1908E-01	-6.9933E-01	1.3709E-01	9.0224E-01	4.3122E+00	1.0405E+00	1.0405E+00	1.0405E+00	1.0405E+00	1.0405E+00
7	1.9528E-01	4.2496E-01	1.4839E-02	1.3717E-01	-5.0004E-01	1.3894E-01	8.9600E-01	2.7445E+00	1.5052E+00	1.5052E+00	1.5052E+00	1.5052E+00	1.5052E+00
8	2.7599E-01	4.7791E-01	6.7947E-02	1.5386E-01	-4.8395E-01	1.4127E-01	8.9588E-01	1.8421E+00	1.9167E+00	1.9167E+00	1.9167E+00	1.9167E+00	1.9167E+00
9	3.7120E-01	5.2127E-01	5.1330E-01	1.6806E-01	-5.1061E-01	1.4585E-01	8.9544E-01	1.2949E+00	2.2612E+00	2.2612E+00	2.2612E+00	2.2612E+00	2.2612E+00
10	4.8944E-01	5.4970E-01	2.6509E-01	1.8045E-01	-1.2104E-01	1.5624E-01	8.9675E-01	8.0104E-01	2.6017E+00	2.6017E+00	2.6017E+00	2.6017E+00	2.6017E+00

N= 3

N	X	Y	Z	U	V	W	SR	RHO	DM	EIASI	EIASX	EIASY	EIASZ
1	-2.5455E-02	4.1911E-06	4.9640E-02	1.5133E-01	-1.4226E-01	1.5945E-01	9.1215E-01	0.2374E+00	2.4757E-01	1.6472E-01	1.6472E-01	1.6472E-01	1.6472E-01
2	2.0226E-02	7.8192E-02	4.7279E-02	3.8559E-01	-1.3915E-01	1.5812E-01	9.0891E-01	0.0927E+00	4.2030E-01	4.2030E-01	4.2030E-01	4.2030E-01	4.2030E-01
3	3.5033E-03	1.5659E-01	4.2763E-02	6.1874E-01	-1.3037E-01	1.5653E-01	9.0308E-01	5.7251E+00	5.7251E+00	5.7251E+00	5.7251E+00	5.7251E+00	5.7251E+00
4	2.6131E-02	2.3241E-01	3.6887E-02	8.4303E-01	-1.1533E-01	1.5144E-01	8.9645E-01	5.2547E+00	8.7125E-01	8.7125E-01	8.7125E-01	8.7125E-01	8.7125E-01
5	6.3804E-02	3.0692E-01	2.9857E-02	1.0517E-01	-1.1354E-01	1.4866E-01	8.8932E-01	4.6173E+00	1.1227E+00	1.1227E+00	1.1227E+00	1.1227E+00	1.1227E+00
6	1.1591E-01	3.7710E-01	2.2527E-02	1.2434E-01	-9.0029E-01	1.4694E-01	8.8160E-01	3.8593E+00	1.3086E+00	1.3086E+00	1.3086E+00	1.3086E+00	1.3086E+00
7	1.8920E-01	4.4726E-01	1.6344E-02	1.4108E-01	-5.7431E-01	1.4546E-01	8.7489E-01	3.1288E+00	1.6537E+00	1.6537E+00	1.6537E+00	1.6537E+00	1.6537E+00
8	2.6014E-01	5.0327E-01	1.1075E-02	1.5554E-01	-1.5819E-01	1.4546E-01	8.7116E-01	2.3948E+00	1.9419E+00	1.9419E+00	1.9419E+00	1.9419E+00	1.9419E+00
9	3.5645E-01	5.5703E-01	7.0232E-01	1.6854E-01	-2.3245E-02	1.4724E-01	8.6861E-01	1.7424E+00	2.2522E+00	2.2522E+00	2.2522E+00	2.2522E+00	2.2522E+00
10	4.7534E-01	5.9999E-01	4.1804E-01	1.7957E-01	-1.3233E-01	1.5091E-01	8.6926E-01	1.2006E+00	2.5011E+00	2.5011E+00	2.5011E+00	2.5011E+00	2.5011E+00

N= 4

N	X	Y	Z	U	V	W	SR	RHO	DM	EIASI	EIASX	EIASY	EIASZ
1	-5.8741E-02	3.6949E-06	4.9050E-02	1.7349E-01	-2.1976E-01	1.7170E-01	9.1148E-01	0.1755E+00	3.1154E-01	1.6472E-01	1.6472E-01	1.6472E-01	1.6472E-01
2	3.5533E-02	8.070E-02	4.6735E-02	4.7281E-01	-2.1398E-01	1.7234E-01	9.0052E-01	0.0539E+00	4.8507E-01	4.8507E-01	4.8507E-01	4.8507E-01	4.8507E-01
3	1.7142E-02	1.6052E-01	4.2703E-02	6.7057E-01	-2.0350E-01	1.6815E-01	8.9837E-01	5.8099E+00	7.1043E-01	7.1043E-01	7.1043E-01	7.1043E-01	7.1043E-01
4	1.0140E-02	2.3895E-01	3.7607E-02	9.0524E-01	-1.7554E-01	1.6343E-01	8.8671E-01	5.4527E+00	9.5097E-01	9.5097E-01	9.5097E-01	9.5097E-01	9.5097E-01
5	4.9301E-02	3.1622E-01	3.0264E-02	1.1190E-01	-1.5373E-01	1.5923E-01	8.7306E-01	4.9041E+00	1.2486E+00	1.2486E+00	1.2486E+00	1.2486E+00	1.2486E+00
6	1.0055E-01	3.9045E-01	2.4359E-02	1.3110E-01	-5.7431E-01	1.4546E-01	8.7116E-01	2.3948E+00	1.9419E+00	1.9419E+00	1.9419E+00	1.9419E+00	1.9419E+00
7	1.6425E-01	4.6167E-01	1.8325E-02	1.4753E-01	-1.5819E-01	1.4546E-01	8.7116E-01	2.3948E+00	1.9419E+00	1.9419E+00	1.9419E+00	1.9419E+00	1.9419E+00
8	2.6336E-01	5.2938E-01	1.3251E-02	1.4102E-01	-1.3233E-01	1.5091E-01	8.6926E-01	1.2006E+00	2.5011E+00	2.5011E+00	2.5011E+00	2.5011E+00	2.5011E+00

1.) FIELD OUTPUT (SAMPLE CASE 1).

FLAME 2 IMETA= 45.00									
SHOCK DATA									
	M	X	Y	Z	U	V	W	SR	RMO
N= 5	1	5.3937E-01	5.9350E-01	1.7226E+01	4.3327E-01	1.5096E+00	8.2230E+00	2.3058E+00	2.3058E+00
	2	4.5734E-01	6.5158E-01	1.8202E+01	5.0373E-01	1.5098E+00	8.2230E+00	1.7097E+00	1.7097E+00
M	3	5.2381E-02	3.3065E-06	1.8746E+00	-5.0259E+00	1.8660E+00	9.1039E+00	0.0705E+00	0.0705E+00
	4	4.7185E-02	8.2354E-02	4.6030E+00	-2.9264E+00	1.8672E+00	9.0410E+00	0.0019E+00	0.0019E+00
	5	3.5113E-03	1.6454E-01	7.2353E+00	-2.7250E+00	1.8803E+00	8.9218E+00	5.8802E+00	5.8802E+00
	6	4.2780E-03	2.4555E-01	5.7404E+00	-2.3643E+00	1.7511E+00	8.7452E+00	5.0705E+00	5.0705E+00
	7	3.4290E-02	3.2567E-01	1.1986E+01	-1.9705E+00	1.7077E+00	8.5285E+00	5.3916E+00	5.3916E+00
	8	4.4344E-02	4.4049E-01	1.3900E+01	-1.3735E+00	1.6741E+00	8.2808E+00	5.0110E+00	5.0110E+00
	9	1.4737E-01	4.8083E-01	2.0594E+02	1.5045E+01	1.6443E+00	8.0039E+00	4.5306E+00	4.5306E+00
	10	4.2520E-01	5.5613E-01	1.5089E+02	1.6996E+01	1.6181E+00	7.7870E+00	4.0007E+00	4.0007E+00
	11	5.2001E-01	6.3077E-01	1.1612E+02	1.8092E+01	1.5949E+00	7.5570E+00	3.4024E+00	3.4024E+00
	12	4.3502E-01	7.0386E-01	8.3427E+01	1.8901E+01	1.5745E+00	7.3739E+00	2.8667E+00	2.8667E+00
M	13	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	9.0408E+00	5.9248E+00	5.9248E+00
	14	6.1133E-02	8.4349E-02	4.4277E+02	3.8041E+00	2.0173E+00	9.0073E+00	5.9220E+00	5.9220E+00
	15	4.5493E-02	1.4864E-01	4.1476E+02	7.7711E+00	1.9224E+00	8.8470E+00	5.9108E+00	5.9108E+00
	16	1.9137E-02	2.5223E-01	3.7410E+02	1.0536E+01	1.8779E+00	8.5943E+00	5.9079E+00	5.9079E+00
	17	1.8256E-02	3.5525E-01	3.2905E+02	1.2917E+01	1.8643E+00	8.2808E+00	5.8955E+00	5.8955E+00
	18	6.7713E-02	4.1792E-01	2.8252E+02	1.4985E+01	1.8159E+00	7.9077E+00	5.8787E+00	5.8787E+00
	19	1.2956E-01	5.0811E-01	2.3406E+02	1.6833E+01	1.7450E+00	7.6539E+00	5.8362E+00	5.8362E+00
	20	2.0556E-01	5.8341E-01	1.9260E+02	1.8233E+01	1.5750E+00	6.9840E+00	5.8238E+00	5.8238E+00
	21	2.9844E-01	6.6858E-01	1.5553E+02	1.9365E+01	1.7291E+00	6.4747E+00	5.7033E+00	5.7033E+00
	22	4.1093E-01	7.5667E-01	1.2526E+02	2.0236E+01	1.7410E+00	5.9640E+00	5.7334E+00	5.7334E+00
	23	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	24	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	25	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	26	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	27	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	28	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	29	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	30	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	31	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	32	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	33	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	34	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	35	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	36	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	37	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	38	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	39	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	40	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	41	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	42	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	43	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	44	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	45	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	46	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	47	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	48	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	49	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	50	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	51	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	52	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	53	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	54	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	55	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	56	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	57	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	58	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	59	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	60	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	61	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	62	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	63	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	64	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	65	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	66	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	67	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	68	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	69	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	70	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	71	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	72	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	73	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	74	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	75	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	76	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	77	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	78	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	79	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	80	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	81	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	82	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	83	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	84	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	85	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	86	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	87	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	88	5.5609E-10	5.7700E-06	6.6371E-02	2.9933E-06	4.5559E+02	2.0714E+00	2.0082E+00	2.0082E+00
	89	5.5609E-10	5.7700						





N	I	Y	P	U	V	M	SR	RMO	MACH	DM
17	5.2789E+00	3.7567E+00	7.1167E+00	1.0014E+01	-4.3121E-01	0.	5.8558E+00	7.6230E+01	4.9385E+00	-0.7945E-02
18	5.9669E+00	3.8742E+00	5.5145E+00	1.1007E+01	-3.2404E-01	0.	5.8500E+00	6.3499E-01	5.1752E+00	-0.1403E-02
N=3										
1	-4.1554E-02	2.9970E-06	1.7290E+02	3.3437E-01	-4.1497E-01	2.0511E-09	6.5111E+00	6.1730E+00	8.5104E-02	4.9548E-03
2	-3.0402E-02	2.4205E-01	1.6781E+02	1.5231E+00	-2.2813E-01	0.	6.4961E+00	0.0007E+00	2.5548E-01	3.6334E-03
3	2.4910E-01	5.0423E-01	1.5313E+02	2.0982E+00	-1.1132E-01	0.	6.4729E+00	5.7224E+00	4.7306E-01	1.7808E-03
4	1.2791E-01	7.2979E-01	1.1457E+02	4.9057E+00	-5.0403E-01	0.	6.4362E+00	4.6972E+00	8.4406E-01	-3.2019E-03
5	3.3325E-01	9.0625E-01	4.7129E+01	6.9337E+00	-2.5440E-01	0.	6.4250E+00	2.4955E+00	1.4431E+00	-4.2435E-02
6	0.0206E-01	1.1570E+00	3.1011E+01	8.2722E+00	-2.6102E+00	0.	6.3450E+00	1.8751E+00	1.7906E+00	-2.7209E-02
7	9.1142E-01	1.3367E+00	2.8135E+01	8.8491E+00	-1.6520E+00	0.	6.3407E+00	1.7768E+00	1.9254E+00	-3.3100E-02
8	1.2803E+00	1.5602E+00	2.7655E+01	9.1002E+00	-1.5946E+00	0.	6.2052E+00	1.7803E+00	1.9903E+00	-3.4705E-03
9	1.7107E+00	1.7864E+00	3.2209E+01	9.1761E+00	-1.4113E+00	0.	6.1905E+00	2.0308E+00	1.9608E+00	2.0373E-03
10	2.1325E+00	2.0770E+00	4.7749E+01	8.5983E+00	-6.3712E-01	0.	6.1105E+00	2.7609E+00	1.7522E+00	9.3532E-03
11	2.5306E+00	2.4002E+00	1.1815E+02	4.8071E+00	4.7124E-01	0.	6.1948E+00	5.1778E+00	0.6204E-01	-5.5558E-02
12	2.9043E+00	2.7605E+00	1.2749E+02	5.0206E+00	3.1161E-01	0.	6.1597E+00	5.5210E+00	8.8046E-01	-4.2314E-02
13	3.2598E+00	3.1017E+00	8.0679E+01	0.9223E+00	1.0322E-01	0.	5.8772E+00	4.2924E+00	1.3456E+00	-0.1299E-02
14	3.6354E+00	3.3790E+00	4.7443E+01	6.6379E+00	5.7018E-01	0.	5.4001E+00	3.2906E+00	1.9268E+00	-9.9714E-02
15	4.0907E+00	3.6102E+00	2.5048E+01	5.7542E+00	3.6004E-01	0.	5.3272E+00	2.1613E+00	2.4346E+00	-1.0098E-01
16	4.6301E+00	3.7772E+00	1.3693E+01	1.0436E+01	1.0013E-01	0.	5.2735E+00	1.4345E+00	2.8520E+00	-1.0054E-01
17	5.2632E+00	3.9380E+00	8.5852E+00	1.0901E+01	-1.4914E-01	0.	5.1939E+00	1.0531E+00	3.2449E+00	-7.2098E-02
18	5.9267E+00	4.1007E+00	6.2904E+00	1.1340E+01	-2.7047E-01	0.	5.2112E+00	8.3918E-01	3.5061E+00	-7.1921E-02
N=6										
N	I	Y	P	U	V	M	SR	RMO	MACH	DM
1	-0.3125E-02	2.8549E-00	1.7227E+02	3.7221E-01	-0.2805E-01	0.	6.5010E+00	0.1000E+00	1.1079E-01	4.5060E-03
2	-5.2343E-03	2.4693E-01	1.6721E+02	1.6494E+00	-4.6730E-01	0.	6.4811E+00	0.8746E+00	2.7529E-01	1.2070E-03
3	2.0237E-03	5.1220E-01	1.5286E+02	3.0349E+00	-3.2439E-01	0.	6.4612E+00	5.7462E+00	5.0023E-01	4.1373E-04
4	1.0430E-01	7.8371E-01	1.1618E+02	4.9599E+00	-7.2075E-01	0.	6.3963E+00	4.0018E+00	8.6114E-01	-4.5715E-03
5	3.0792E-01	1.0122E+00	3.2581E+01	6.9387E+00	-2.5202E+00	0.	6.3781E+00	2.8140E+00	1.4040E+00	-3.01125E-02
6	5.7566E-01	1.1894E+00	5.3707E+01	8.3546E+00	-2.5842E+00	0.	6.3171E+00	1.9879E+00	1.8209E+00	-1.7041E-02
7	8.7995E-01	1.3790E+00	2.7142E+01	9.0909E+00	-2.7973E+00	0.	6.2215E+00	1.7667E+00	2.0369E+00	-4.9550E-03
8	1.2526E+00	1.5901E+00	2.6494E+01	9.4709E+00	-2.8308E+00	0.	6.1052E+00	1.8154E+00	2.1429E+00	3.0034E-03
9	1.6710E+00	1.8350E+00	3.0169E+01	9.5827E+00	-1.0596E+00	0.	5.9570E+00	2.0076E+00	2.1050E+00	7.9317E-03
10	2.0976E+00	2.1195E+00	4.4090E+01	5.3086E+00	-1.1240E+00	0.	5.7830E+00	2.8033E+00	2.0323E+00	7.2523E-03
11	2.5862E+00	2.4732E+00	1.1450E+02	5.8394E+00	-1.5960E-01	0.	5.9299E+00	5.4240E+00	1.0700E+00	-6.8005E-02
12	2.6877E+00	2.7810E+00	1.2924E+02	5.8906E+00	3.5467E-01	0.	5.8639E+00	6.0531E+00	1.0776E+00	-5.4252E-02
13	3.2403E+00	3.1244E+00	8.3796E+01	7.8096E+00	2.8028E-01	0.	5.3671E+00	5.0151E+00	1.8375E+00	-9.0040E-02
14	3.6106E+00	3.6314E+00	5.1430E+01	9.6048E+00	6.4466E-01	0.	4.7953E+00	4.2342E+00	2.3306E+00	-0.9434E-02
15	4.0582E+00	3.7062E+00	3.0274E+01	1.9566E+01	8.5850E-01	0.	4.5620E+00	3.1034E+00	2.8003E+00	-7.5620E-02
16	4.5973E+00	3.9132E+00	1.8224E+01	1.1052E+01	6.4578E-01	0.	4.5178E+00	2.1979E+00	3.2203E+00	-7.3303E-02
17	5.2012E+00	4.1214E+00	1.1902E+01	1.1416E+01	2.9579E-01	0.	4.449E+00	1.6551E+00	3.5072E+00	-7.3146E-02
18	5.8796E+00	4.3270E+00	8.4527E+00	1.1080E+01	-1.9838E-02	0.	4.4460E+00	1.2719E+00	3.8251E+00	-0.3093E-02
N=5										
N	I	Y	P	U	V	M	SR	RMO	MACH	DM
1	-0.5201E-02	2.7200E-04	1.7126E+02	3.6804E-01	-8.4042E-01	1.4696E-09	6.4709E+00	6.2090E+00	1.4005E-01	-7.4543E-03
2	-7.4654E-02	2.5171E-01	1.6135E+02	1.7279E+00	-6.7233E-01	0.	6.4710E+00	6.0743E+00	2.5944E-01	-1.2044E-03
3	-1.9524E-02	5.2020E-01	1.5235E+02	3.1783E+00	-5.4450E-01	0.	6.4350E+00	5.7637E+00	5.3000E-01	2.5935E-04
4	8.4433E-02	7.9449E-01	1.1793E+02	5.9408E+00	-9.2279E-01	0.	6.3540E+00	4.9009E+00	8.8499E-01	-4.4409E-03
5	2.0201E-01	1.0303E+00	0.1676E+01	6.9348E+00	-2.1737E-01	0.	6.3223E+00	3.1200E+00	1.3015E+00	-2.4571E-02
6	5.4300E-01	1.2211E+00	3.6040E+01	8.3045E+00	-2.6090E+00	0.	6.2350E+00	2.1766E+00	1.8240E+00	-1.2105E-02
7	8.4735E-01	1.4224E+00	2.7110E+01	9.2504E+00	-1.6144E+00	0.	6.0940E+00	1.8503E+00	2.1244E+00	-1.2002E-03
8	1.2162E+00	1.6343E+00	2.5406E+01	9.7502E+00	-2.4784E+00	0.	5.9007E+00	1.8551E+00	2.3024E+00	5.3219E-03
9	1.6730E+00	1.8864E+00	2.7937E+01	1.0012E+01	-2.5348E+00	0.	5.6077E+00	2.1566E+00	2.6046E+00	7.3235E-03
10	2.0627E+00	2.1618E+00	3.9066E+01	1.0076E+01	-1.7031E+00	0.	5.3014E+00	3.0300E+00	2.3723E+00	9.6157E-03
11	2.4817E+00	2.4603E+00	1.0705E+02	7.0017E+00	3.0057E-01	0.	5.5480E+00	5.8124E+00	1.3947E+00	-7.0002E-02
12	2.8711E+00	2.8070E+00	1.3169E+02	7.8315E+00	4.0207E-01	0.	5.5480E+00	6.8027E+00	1.3599E+00	-3.9672E-02
13	3.2209E+00	3.1555E+00	8.8344E+01	8.9749E+00	5.4243E-01	0.	4.7088E+00	6.2042E+00	2.0209E+00	-6.2075E-02
14	3.5847E+00	3.4855E+00	5.7066E+01	1.0390E+01	1.1060E+00	0.	4.1932E+00	5.4231E+00	2.7235E+00	-0.2375E-02
15	4.0238E+00	3.7908E+00	3.7032E+01	1.1103E+01	1.2505E+00	0.	3.9709E+00	4.2559E+00	3.1540E+00	-4.7704E-02
16	4.5549E+00	4.0500E+00	2.5194E+01	1.1437E+01	1.0007E+00	0.	3.9159E+00	3.2734E+00	3.4994E+00	-4.0991E-02
17	5.1535E+00	4.3047E+00	1.7916E+01	1.1602E+01	8.7908E-01	0.	3.8707E+00	2.5027E+00	3.7306E+00	-0.1124E-02
18	5.8250E+00	4.5534E+00	1.2708E+01	1.1730E+01	2.8904E-01	0.	3.9434E+00	1.9922E+00	3.9204E+00	-0.0701E-02
N=6										
N	I	Y	P	U	V	M	SR	RMO	MACH	DM
1	-1.0776E-01	2.6144E-00	1.6997E+02	3.6997E+00	-1.0776E-01	1.4696E-09	6.4709E+00	6.2090E+00	1.4005E-01	-7.4543E-03
2	-9.7334E-02	2.5048E-01	1.6135E+02	1.7279E+00	-6.7233E-01	0.	6.4710E+00	6.0743E+00	2.5944E-01	-1.2044E-03

m. (cont'd.) FIELD OUTPUT (SAMPLE CASE 2).

[illegible]

Y 1.4762E+00 2.0750E+00 2.4390E+01 1.7120E+01 -3.0744E+00 4.0507E+00 3.0955E+00 3.5047E+00 1.7994E-03  
 10 1.9225E+00 2.3205E+00 2.7878E+01 1.1585E+01 -4.0304E+00 3.5363E+00 3.5426E+00 4.0127E+00 0.2355E-03  
 11 2.3841E+00 2.5825E+00 4.7390E+01 1.1756E+01 -2.0653E+00 3.0165E+00 0.0470E+00 0.8133E+00 -9.0190E-04  
 12 2.8050E+00 2.8024E+00 1.0444E+02 1.1175E+01 -3.2653E+00 3.5146E+00 1.1695E+01 2.1605E+00 -0.0002E-02  
 13 3.1428E+00 3.2677E+00 1.1077E+02 9.7077E+00 1.4606E+00 4.2284E+00 8.6225E+00 2.3150E+00 -0.0039E-02  
 14 3.4717E+00 3.7040E+00 8.8474E+01 8.7596E+00 1.7315E+00 5.2965E+00 5.4122E+00 1.0605E+00 -0.0213E-03  
 15 3.8672E+00 4.1662E+00 6.9097E+01 8.5394E+00 1.6091E+00 5.7528E+00 3.9617E+00 1.7795E+00 0.0043E-03  
 16 4.3496E+00 4.6107E+00 5.5152E+01 8.4620E+00 1.2035E+00 5.0618E+00 3.2856E+00 1.0040E+00 -7.1002E-03  
 17 4.9097E+00 5.0446E+00 4.3820E+01 8.9898E+00 9.4123E-01 5.7191E+00 2.9038E+00 1.9005E+00 -0.1201E-02  
 18 5.5470E+00 5.6597E+00 5.4147E+01 1.4702E+00 0.0070E-01 5.3693E+00 2.6035E+00 2.2513E+00 -0.2203E-02

N=10  
 M 1 -2.0265E-01 2.2674E-06 1.6062E+02 4.9193E-01 -2.0760E+00 0.5008E+00 5.8737E+00 5.4401E-01 2.9790E-03  
 2 -1.0172E-01 2.7444E-01 1.5608E+02 2.1301E+00 -1.0325E+00 0.4409E+00 5.8566E+00 4.7098E-01 7.9907E-04  
 3 -1.3535E-01 5.5979E-01 1.4542E+02 4.0049E+00 -1.7960E+00 0.3041E+00 5.7074E+00 7.6000E-01 -1.1724E-03  
 4 -2.8813E-02 8.4835E-01 1.2424E+02 5.9584E+00 -1.9152E+00 0.2378E+00 5.5809E+00 1.1211E+00 -1.9517E-03  
 5 1.4396E-01 1.1225E+00 9.2533E+01 7.8000E+00 -2.2478E+00 0.50055F+00 5.0320E+00 1.5948E+00 -3.5202E-03  
 6 3.7685E-01 1.3778E+00 6.5435E+01 9.3104E+00 -2.4609E+00 3.2023E+00 4.4021E+00 2.1501E+00 -2.3006E-03  
 7 6.6835E-01 1.6272E+00 4.6433E+01 1.0406E+00 -2.7659E+00 4.5690E+00 4.0092E+00 2.6909E+00 7.0371E-04  
 8 1.0240E+00 1.8749E+00 3.4639E+01 1.1102E+00 -3.2312E+00 4.1106E+00 3.6871E+00 5.2737E+00 3.5091E-03  
 9 1.4365E+00 2.1223E+00 2.7780E+01 1.1794E+00 -3.7737E+00 3.9462E+00 3.4608E+00 5.8245E+00 5.1030E-03  
 10 1.8073E+00 2.3708E+00 2.4555E+01 1.1720E+00 -4.1593E+00 3.5527E+00 4.1207E+00 4.3081E+00 5.9059E-03  
 11 2.7597E+00 2.6116E+00 3.4755E+01 1.1894E+00 -4.5458E+00 2.7538E+00 5.7415E+00 4.2549E+00 2.1223E-03  
 12 2.7805E+00 3.2921E+00 8.1416E+01 1.1016E+00 -5.7765E+00 3.4522E+00 8.6303E+00 3.0367E+00 -3.9259E-02  
 13 3.1231E+00 3.7684E+00 1.0057E+02 8.9080E+00 1.3718E+00 4.9350E+00 6.9490E+00 1.9273E+00 -2.4530E-02  
 14 3.6416E+00 4.2083E+00 9.4842E+01 6.1371E+00 1.7101E+00 5.5517E+00 5.2355E+00 1.6508E+00 3.1037E-03  
 15 3.8235E+00 4.7530E+00 7.5856E+01 6.3991E+00 1.5393E+00 5.6020E+00 4.6435E+00 1.7407E+00 -1.5223E-02  
 16 4.2807E+00 5.2731E+00 6.0944E+01 9.0048E+00 1.3085E+00 5.4419E+00 4.0221E+00 1.9762E+00 -3.2945E-02  
 17 4.8030E+00 5.7311E+00 4.9121E+01 9.6052E+00 1.1650E+00 5.1074E+00 3.7523E+00 2.2714E+00 -4.7078E-02  
 18 5.4623E+00 5.6808E+00 3.9363E+01 1.0214E+00 8.3654E-01 4.7282E+00 3.5690E+00 2.6003E+00 -0.7656E-02

N=11  
 M 1 -2.2740E-01 2.1900E-06 1.5602E+02 5.0048E-01 -2.3715E+00 0.4913E+00 5.7048E+00 5.9308E-01 0.9633E-05  
 2 -2.1623E-01 2.7887E-01 1.5321E+02 2.2205E+00 -2.2235E+00 0.4390E+00 5.7407E+00 5.1580E-01 1.5723E-04  
 3 -1.5937E-01 5.6761E-01 1.4274E+02 4.2074E+00 -2.0910E+00 0.2714E+00 5.7647E+00 7.0904E-01 9.8950E-05  
 4 -5.2279E-02 8.5977E-01 1.2450E+02 6.2241E+00 -2.1461E+00 0.5047E+00 5.7310E+00 1.1539E+00 4.1023E-05  
 5 1.1409E-01 1.1422E+00 9.8365E+01 8.2020E+00 -2.3948E+00 5.0023E+00 5.6047E+00 2.7422E+00 -3.0030E-05  
 6 3.4020E-01 1.4088E+00 7.4107E+01 9.7874E+00 -2.5145E+00 4.7372E+00 5.5031E+00 2.3400E+00 -1.0323E-04  
 7 6.2054E-01 1.6669E+00 5.5057E+01 1.0011E+00 -2.7325E+00 4.7812E+00 5.4260E+00 2.9285E+00 -1.2002E-04  
 8 9.8348E-01 1.9244E+00 4.1666E+01 1.1396E+00 -3.1448E+00 5.3199E+00 5.2608E+00 3.5433E+00 -7.5630E-05  
 9 1.3964E+00 2.1607E+00 3.2955E+01 1.1687E+00 -3.6735E+00 5.8369E+00 5.1025E+00 4.0715E+00 -2.1016E-04  
 10 1.8520E+00 2.4113E+00 2.7300E+01 1.1825E+00 -4.1151E+00 6.9489E+00 4.9489E+00 4.9489E+00 3.2297E-05  
 11 2.3535E+00 2.6408E+00 2.8561E+01 1.1639E+00 -3.8062E+00 6.7573E+00 4.9879E+00 4.9879E+00 6.0218E-04  
 12 2.7728E+00 2.9220E+00 6.1476E+01 1.0795E+00 -4.2019E+00 6.3419E+00 5.4013E+00 2.7410E+00 5.0073E-05  
 13 3.1933E+00 3.3230E+00 1.0283E+02 8.2727E+00 1.1594E+00 5.5844E+00 5.6745E+00 1.6590E+00 5.9055E-03  
 14 3.6103E+00 3.8172E+00 1.0114E+02 7.8126E+00 1.7282E+00 5.6040E+00 5.6753E+00 1.6017E+00 -3.7026E-02  
 15 3.7782E+00 4.3550E+00 8.4678E+01 6.6802E+00 1.7590E+00 5.0507E+00 5.6140E+00 1.9274E+00 -5.0133E-02  
 16 4.2264E+00 4.8908E+00 6.9196E+01 9.7239E+00 1.6777E+00 4.6251E+00 5.5382E+00 2.3492E+00 -3.0142E-02  
 17 4.7586E+00 5.4183E+00 5.7016E+01 1.0706E+00 1.4701E+00 4.1771E+00 5.4444E+00 2.8226E+00 -4.7090E-02  
 18 5.3719E+00 5.9141E+00 4.5681E+01 1.1413E+00 1.0014E+00 3.7022E+00 5.3220E+00 3.3075E+00 -1.9018E-02

PLANE 2 THETA= 22.50  
 SHOCK DATA  
 N 1 -3.9825E-11 3.3404E-06 1.5602E+02 5.0048E-01 -2.3715E+00 0.4913E+00 5.7048E+00 5.9308E-01 0.9633E-05  
 2 -2.1623E-01 2.7887E-01 1.5321E+02 2.2205E+00 -2.2235E+00 0.4390E+00 5.7407E+00 5.1580E-01 1.5723E-04  
 3 -1.5937E-01 5.6761E-01 1.4274E+02 4.2074E+00 -2.0910E+00 0.2714E+00 5.7647E+00 7.0904E-01 9.8950E-05  
 4 -5.2279E-02 8.5977E-01 1.2450E+02 6.2241E+00 -2.1461E+00 0.5047E+00 5.7310E+00 1.1539E+00 4.1023E-05  
 5 1.1409E-01 1.1422E+00 9.8365E+01 8.2020E+00 -2.3948E+00 5.0023E+00 5.6047E+00 2.7422E+00 -3.0030E-05  
 6 3.4020E-01 1.4088E+00 7.4107E+01 9.7874E+00 -2.5145E+00 4.7372E+00 5.5031E+00 2.3400E+00 -1.0323E-04  
 7 6.2054E-01 1.6669E+00 5.5057E+01 1.0011E+00 -2.7325E+00 4.7812E+00 5.4260E+00 2.9285E+00 -1.2002E-04  
 8 9.8348E-01 1.9244E+00 4.1666E+01 1.1396E+00 -3.1448E+00 5.3199E+00 5.2608E+00 3.5433E+00 -7.5630E-05  
 9 1.3964E+00 2.1607E+00 3.2955E+01 1.1687E+00 -3.6735E+00 5.8369E+00 5.1025E+00 4.0715E+00 -2.1016E-04  
 10 1.8520E+00 2.4113E+00 2.7300E+01 1.1825E+00 -4.1151E+00 6.9489E+00 4.9489E+00 4.9489E+00 3.2297E-05  
 11 2.3535E+00 2.6408E+00 2.8561E+01 1.1639E+00 -3.8062E+00 6.7573E+00 4.9879E+00 4.9879E+00 6.0218E-04  
 12 2.7728E+00 2.9220E+00 6.1476E+01 1.0795E+00 -4.2019E+00 6.3419E+00 5.4013E+00 2.7410E+00 5.0073E-05  
 13 3.1933E+00 3.3230E+00 1.0283E+02 8.2727E+00 1.1594E+00 5.5844E+00 5.6745E+00 1.6590E+00 5.9055E-03  
 14 3.6103E+00 3.8172E+00 1.0114E+02 7.8126E+00 1.7282E+00 5.6040E+00 5.6753E+00 1.6017E+00 -3.7026E-02  
 15 3.7782E+00 4.3550E+00 8.4678E+01 6.6802E+00 1.7590E+00 5.0507E+00 5.6140E+00 1.9274E+00 -5.0133E-02  
 16 4.2264E+00 4.8908E+00 6.9196E+01 9.7239E+00 1.6777E+00 4.6251E+00 5.5382E+00 2.3492E+00 -3.0142E-02  
 17 4.7586E+00 5.4183E+00 5.7016E+01 1.0706E+00 1.4701E+00 4.1771E+00 5.4444E+00 2.8226E+00 -4.7090E-02  
 18 5.3719E+00 5.9141E+00 4.5681E+01 1.1413E+00 1.0014E+00 3.7022E+00 5.3220E+00 3.3075E+00 -1.9018E-02

STEP 500 TIME= 4.98575E-01

PLANE 1      TIME= 0.00

## SMOCK DATA

M		X0		Y0		X5		Y5		A15		ETAS		ETAS1		E1304		E1A321		ELASIM	
1	2.2000E-01	3.0182E-04	1.2747E-01	2.1622E-04	0.	0.	2.5329E-01	1.7646E-04	1.9618E-04	1.5200E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	2.2603E-01	1.0437E-01	1.2302E-01	1.1912E-01	1.0078E-01	0.	2.6295E-01	3.6709E-04	4.1307E-04	1.2603E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	2.3170E-01	2.2606E-01	1.2594E-01	2.4116E-01	2.1356E-01	0.	2.7616E-01	3.3924E-04	3.8038E-04	1.1508E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	2.3708E-01	3.2915E-01	1.6648E-01	3.0345E-01	2.8046E-01	0.	2.8046E-01	3.4554E-04	4.0159E-04	0.8173E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	2.4246E-01	4.2645E-01	1.9349E-01	4.6712E-01	4.2712E-01	0.	2.9047E-01	3.4541E-04	4.0159E-04	0.6373E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	2.4784E-01	5.2701E-01	2.3741E-01	5.0237E-01	5.3390E-01	0.	2.9645E-01	3.5515E-04	4.4446E-04	0.4307E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	2.5322E-01	6.2174E-01	3.0219E-01	6.0214E-01	6.4080E-01	0.	2.9711E-01	3.7068E-04	4.8716E-04	0.2455E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	2.5860E-01	7.1747E-01	3.9725E-01	7.0708E-01	7.4766E-01	0.	3.0008E-01	3.7068E-04	5.2457E-04	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	2.6398E-01	8.1424E-01	4.9028E-01	8.0246E-01	8.5246E-01	0.	3.0412E-01	4.1168E-04	6.0116E-04	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	2.6936E-01	9.1101E-01	5.8246E-01	5.7086E-01	6.2095E-01	0.	3.0808E-01	4.5297E-04	7.0726E-04	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	2.7474E-01	1.0180E-01	6.6994E-01	1.3207E-01	1.1746E-01	0.	3.1208E-01	4.9614E-04	8.0614E-04	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	2.8012E-01	1.1200E-01	7.5725E-01	1.4574E-01	1.2841E-01	0.	3.1608E-01	5.3924E-04	9.0159E-04	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	2.8550E-01	1.2218E-01	8.4555E-01	1.5949E-01	1.4080E-01	0.	3.2012E-01	5.8246E-04	1.0047E-01	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	2.9088E-01	1.3235E-01	9.3425E-01	1.7316E-01	1.5246E-01	0.	3.2416E-01	6.2554E-04	1.1047E-01	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	2.9626E-01	1.4252E-01	1.0280E-01	1.8601E-01	1.6494E-01	0.	3.2820E-01	6.6864E-04	1.2047E-01	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	3.0164E-01	1.5269E-01	1.1297E-01	1.9949E-01	1.7746E-01	0.	3.3224E-01	7.1174E-04	1.3047E-01	0.1047E-01	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	3.0702E-01	1.6286E-01	1.2306E-01	2.1297E-01																	

N=3									
X	Y	P	U	V	W	SR	RHO	MALH	DM
1 1.0609E-01	2.5899E-06	2.2711E+02	9.9100E-01	-8.6007E-01	5.1945E-09	7.1820E+00	0.1925E+00	1.8191E-01	1.8509E-04
2 1.8505E-01	1.1348E-01	2.1578E+02	2.5433E+00	-7.7140E-01	0.	7.1518E+00	0.0219E+00	5.7520E-01	-1.8011E-03
3 1.9054E-01	2.2889E-01	2.0221E+02	4.0356E+00	-6.4764E-01	0.	7.1008E+00	5.8669E-01	5.8669E-01	3.7743E-03
4 2.7430E-01	3.4248E-01	1.6430E+02	5.7508E+00	-8.0532E-01	0.	7.0450E+00	5.1099E+00	0.6551E-01	1.5062E-03
5 2.5341E-01	4.5272E-01	1.2311E+02	7.3042E+00	-1.1559E-01	0.	6.9832E+00	4.2321E+00	1.1559E+00	3.1652E-06
6 3.1421E-01	5.5708E-01	9.2474E+01	6.5564E+00	-1.3322E+00	0.	6.9094E+00	5.5234E+00	1.4286E+00	1.2549E-03
7 3.9218E-01	6.5849E-01	7.2078E+01	9.5097E+00	-1.3411E+00	0.	6.8525E+00	1.6017E+00	1.6017E+00	3.3018E-03
8 4.3659E-01	7.5593E-01	5.5834E+01	1.0288E+01	-1.2844E+00	0.	6.7751E+00	2.5080E+00	1.8192E+00	5.0004E-03
9 5.9339E-01	8.5005E-01	4.7688E+01	1.0967E+01	-1.1273E+00	0.	6.6875E+00	2.1004E+00	2.0950E+00	0.1904E-03
10 7.1471E-01	9.4257E-01	3.3077E+01	1.1542E+01	-9.7474E-01	0.	6.6109E+00	1.8309E+00	2.3070E+00	7.1203E-03
11 8.4942E-01	1.0365E+00	2.5466E+01	1.2008E+01	-8.7474E-01	0.	6.5743E+00	1.5434E+00	2.5050E+00	7.9731E-03
12 1.0031E+00	1.1245E+00	1.9892E+01	1.2415E+01	-7.5049E-01	0.	6.5107E+00	1.3145E+00	2.7023E+00	6.7143E-03
13 1.1718E+00	1.2151E+00	1.5603E+01	1.2737E+01	-6.8672E-01	0.	6.4877E+00	1.1100E+00	2.8003E+00	9.2541E-03
14 1.3684E+00	1.3029E+00	1.2501E+01	1.3027E+01	-7.0275E-01	0.	6.4441E+00	9.6305E-01	3.0004E+00	9.7530E-03
15 1.5660E+00	1.3945E+00	1.0372E+01	1.3265E+01	-7.1692E-01	0.	6.3784E+00	8.5933E-01	3.2517E+00	1.0013E-02
16 1.7878E+00	1.4929E+00	9.0033E+00	1.3456E+01	-6.9363E-01	0.	6.3303E+00	7.9351E-01	3.3806E+00	9.9701E-03
17 2.0272E+00	1.5947E+00	8.0744E+00	1.3607E+01	-6.5314E-01	0.	6.2260E+00	7.5056E-01	3.5103E+00	5.7010E-03
18 2.2836E+00	1.7008E+00	7.3984E+00	1.3731E+01	-6.1662E-01	0.	6.1488E+00	7.2085E-01	3.6201E+00	9.2571E-03
N=4									
X	Y	P	U	V	W	SR	RHO	MALH	DM
1 1.6566E-01	2.4200E-06	2.2295E+02	1.1437E+00	-1.3033E+00	2.7523E-09	7.1794E+00	0.1156E+00	2.4709E-01	-1.1145E-04
2 1.6473E-01	1.1555E-01	2.1248E+02	2.8537E+00	-1.2691E+00	0.	7.1322E+00	5.9094E+00	4.4190E-01	-1.3000E-03
3 1.6841E-01	2.3312E-01	1.9907E+02	4.3814E+00	-1.1124E+00	0.	7.0755E+00	5.8272E+00	6.5408E-01	3.3033E-03
4 1.9220E-01	3.4937E-01	1.6746E+02	6.0327E+00	-1.1024E+00	0.	6.9562E+00	5.3101E+00	9.2402E-01	4.2512E-04
5 2.3075E-01	4.5296E-01	1.3133E+02	7.5912E+00	-1.3621E+00	0.	6.8272E+00	4.6340E+00	1.2744E+00	-2.0202E-03
6 2.8943E-01	5.7213E-01	1.0052E+02	8.9376E+00	-1.4647E+00	0.	6.6711E+00	4.0031E+00	1.5287E+00	-1.9905E-03
7 3.6450E-01	6.7900E-01	7.8734E+01	1.0010E+01	-1.4688E+00	0.	6.4972E+00	3.5337E+00	1.8119E+00	1.0701E-03
8 4.6300E-01	7.8311E-01	6.2824E+01	1.0435E+01	-1.3523E+00	0.	6.3590E+00	3.1464E+00	2.0500E+00	2.2678E-03
9 5.6663E-01	8.8572E-01	5.0005E+01	1.1517E+01	-1.1181E+00	0.	6.1892E+00	2.7900E+00	2.3101E+00	3.7515E-03
10 6.7925E-01	9.8720E-01	3.9608E+01	1.2089E+01	-9.0751E-01	0.	6.0436E+00	2.4072E+00	2.5400E+00	4.7055E-03
11 8.1153E-01	1.0909E+00	3.1478E+01	1.2537E+01	-7.2374E-01	0.	5.9514E+00	2.1578E+00	2.7709E+00	5.5022E-03
12 9.6184E-01	1.1918E+00	2.5154E+01	1.2923E+01	-5.7116E-01	0.	5.8133E+00	1.9015E+00	3.0059E+00	6.0124E-03
13 1.1274E+00	1.2960E+00	2.0255E+01	1.3228E+01	-4.6876E-01	0.	5.7255E+00	1.6713E+00	3.2133E+00	6.3907E-03
14 1.3117E+00	1.3998E+00	1.6445E+01	1.3496E+01	-4.4478E-01	0.	5.6264E+00	1.4413E+00	3.4232E+00	6.4978E-03
15 1.5128E+00	1.5075E+00	1.3591E+01	1.3737E+01	-4.7625E-01	0.	5.5100E+00	1.3359E+00	3.6408E+00	6.3971E-03
16 1.7301E+00	1.6213E+00	1.1478E+01	1.3937E+01	-5.2749E-01	0.	5.3424E+00	1.2280E+00	3.8554E+00	6.0356E-03
17 1.9648E+00	1.7387E+00	9.9487E+00	1.4108E+01	-5.7392E-01	0.	5.2489E+00	1.1518E+00	4.0004E+00	5.6305E-03
18 2.2162E+00	1.8663E+00	8.8326E+00	1.4251E+01	-6.1698E-01	0.	5.1129E+00	1.0995E+00	4.2543E+00	5.0767E-03
N=5									
X	Y	P	U	V	W	SR	RHO	MALH	DM
1 1.4692E-01	2.2861E-06	2.1763E+02	1.3077E+00	-1.9942E+00	-4.9772E-11	7.1764E+00	0.0161E+00	3.2402E-01	3.9746E-04
2 1.4406E-01	1.1763E-01	2.0750E+02	3.1545E+00	-1.7517E+00	0.	7.1109E+00	5.9247E+00	5.1529E-01	-7.7298E-04
3 1.4788E-01	2.3741E-01	1.9590E+02	4.7013E+00	-1.5756E+00	0.	7.0110E+00	5.8497E+00	7.2414E-01	2.4000E-03
4 1.6960E-01	3.5640E-01	1.6932E+02	6.4575E+00	-1.5475E+00	0.	6.8577E+00	5.5566E+00	1.0357E+00	-1.2947E-03
5 2.0744E-01	4.7531E-01	1.3880E+02	8.1073E+00	-1.6007E+00	0.	6.6063E+00	5.1350E+00	1.3435E+00	-3.3313E-03
6 2.6383E-01	5.8723E-01	1.0995E+02	9.5421E+00	-1.6425E+00	0.	6.3340E+00	4.6946E+00	1.6518E+00	-3.3622E-03
7 3.3668E-01	6.9955E-01	8.7852E+01	1.0081E+01	-1.5970E+00	0.	6.0431E+00	4.3505E+00	2.0311E+00	-1.5331E-03
8 4.2482E-01	8.1044E-01	7.1776E+01	1.1336E+01	-1.4065E+00	0.	5.7711E+00	4.0701E+00	2.3590E+00	5.0722E-04
9 5.2623E-01	9.2100E-01	5.9135E+01	1.2203E+01	-1.1215E+00	0.	5.5179E+00	3.8100E+00	2.6208E+00	1.6474E-03
10 6.4770E-01	1.0320E+00	4.0040E+01	1.3155E+01	-8.3941E-01	0.	5.2622E+00	3.5446E+00	2.9119E+00	2.1977E-03
11 7.7122E-01	1.1454E+00	2.7533E+01	1.3779E+01	-6.0088E-01	0.	5.0745E+00	3.2713E+00	3.1822E+00	2.5010E-03
12 9.1743E-01	1.2593E+00	3.3155E+01	1.3501E+01	-4.0356E-01	0.	4.8746E+00	3.0206E+00	3.4501E+00	2.6166E-03
13 1.0791E+00	1.3767E+00	2.7533E+01	1.3779E+01	-2.7404E-01	0.	4.6954E+00	2.7882E+00	3.7067E+00	2.6304E-03
14 1.2585E+00	1.4902E+00	2.3062E+01	1.4015E+01	-2.1245E-01	0.	4.5277E+00	2.5819E+00	3.9619E+00	2.4914E-03
15 1.4546E+00	1.6199E+00	1.9555E+01	1.4219E+01	-2.1034E-01	0.	4.3511E+00	2.4211E+00	4.2211E+00	2.2299E-03
16 1.6671E+00	1.7487E+00	1.4738E+01	1.4396E+01	-2.5372E-01	0.	4.1730E+00	2.2713E+00	4.4625E+00	1.9538E-03
17 1.8966E+00	1.8814E+00	1.4503E+01	1.4548E+01	-3.2357E-01	0.	3.9949E+00	2.1573E+00	4.7453E+00	1.6003E-03
18 2.1428E+00	2.0183E+00	1.2746E+01	1.4679E+01	-4.0454E-01	0.	3.8181E+00	2.0691E+00	5.0001E+00	1.4620E-03
N=6									
X	Y	P	U	V	W	SR	RHO	MALH	DM
1 1.2787E-01	2.1652E-06	2.0030E+02	1.5 n. (cont'd.)	FIELD OUTPUT (SAMPLE CASE 3)	6.7E+00	4.1411E-01	1.9076E-03	4.1411E-01	1.9076E-03
2 1.2302E-01	1.1972E-01	2.0104E+02	3.4444E+00	-2.0270E+00	1.0605E-10	7.0679E+00	3.0310E+00	3.9366E-01	4.0070E-03

3	1.2590E-01	2.4170E-01	1.9077E+02	4.9848E+00	-2.0457E+00	1.7643E-16	6.9618E+00	3.8221E+00	7.9556E-01	3.7444E-05
4	1.6648E-01	3.4333E-01	1.6864E+02	7.1125E+00	-2.0064E+00	9.4045E-17	6.6699E+00	5.7998E+00	1.1577E+00	5.6549E-05
5	1.8349E-01	4.8376E-01	1.4551E+02	8.9444E+00	-1.9012E+00	6.2511E-17	6.3368E+00	5.7690E+00	1.5226E+00	5.5149E-05
6	2.3741E-01	6.0237E-01	1.2119E+02	1.0343E+01	-1.8008E+00	4.0110E-17	5.8665E+00	5.7248E+00	1.9264E+00	5.4244E-05
7	3.0752E-01	7.2014E-01	1.0870E+02	1.1461E+01	-1.6584E+00	3.1440E-17	5.4560E+00	5.6720E+00	2.3229E+00	5.4330E-05
8	3.9212E-01	8.3790E-01	8.4665E+01	1.2271E+01	-1.4179E+00	3.9320E-17	5.0637E+00	5.6148E+00	2.8654E+00	5.5337E-05
9	4.9020E-01	9.5646E-01	7.2215E+01	1.2890E+01	-1.1671E+00	5.6516E-17	4.6992E+00	5.5255E+00	3.0317E+00	5.6142E-05
10	6.0209E-01	1.0708E+00	6.1663E+01	1.3374E+01	-7.5915E-01	7.4639E-17	4.3557E+00	5.4643E+00	3.3708E+00	5.7544E-05
11	7.2844E-01	1.2000E+00	5.3369E+01	1.3752E+01	-6.7179E-01	6.9265E-17	4.0359E+00	5.4105E+00	3.7024E+00	5.9951E-05
12	8.6994E-01	1.3267E+00	4.6311E+01	1.4054E+01	-5.3082E-01	1.0006E-16	3.7311E+00	5.3309E+00	4.0306E+00	6.4028E-05
13	1.0272E+00	1.4574E+00	4.0355E+01	1.4301E+01	-3.7150E-02	1.0500E-16	3.4438E+00	5.2450E+00	4.3776E+00	6.8053E-05
14	1.2010E+00	1.5923E+00	3.5394E+01	1.4503E+01	2.3940E-02	1.0621E-16	3.1769E+00	5.1545E+00	4.6774E+00	7.2827E-05
15	1.3915E+00	1.7316E+00	3.1242E+01	1.4669E+01	5.9809E-02	1.0274E-16	2.9295E+00	5.0602E+00	4.9894E+00	7.8021E-05
16	1.5989E+00	1.8752E+00	2.7716E+01	1.4808E+01	4.8263E-02	9.6096E-02	2.6988E+00	4.9619E+00	5.2554E+00	8.4050E-05
17	1.8229E+00	2.0230E+00	2.4704E+01	1.4926E+01	2.3335E-03	9.7410E-17	2.4637E+00	4.8601E+00	5.5545E+00	9.0670E-05
18	2.0636E+00	2.1788E+00	2.2126E+01	1.5026E+01	-6.6465E-02	7.7730E-17	2.2643E+00	4.7556E+00	5.8676E+00	9.8050E-05

PLANE 2 THETA= 22.50

# SHOCK DATA

N	X	Y	Z	U	V	W	SR	RHO	MACH	DN
1	2.2000E-01	2.9773E-06	1.2787E-01	2.1652E-06	1.9493E-06	2.5406E-01	1.7521E-04	1.7018E-04	1.4043E-01	0.0
2	2.2457E-01	1.1004E-01	1.2176E-01	1.2044E-01	1.0701E-01	2.5922E-01	3.0481E-04	3.4460E-04	1.0608E-01	-1.6011E-03
3	2.3293E-01	2.2239E-01	1.3157E-01	2.4343E-01	2.1403E-01	2.7280E-01	3.1382E-04	3.6104E-04	1.1851E-01	-2.7942E-03
4	2.6067E-01	3.3185E-01	1.5365E-01	3.6617E-01	3.2104E-01	4.8091E-01	3.4607E-04	4.0849E-04	5.9478E-02	-9.6260E-03
5	3.0422E-01	4.3555E-01	1.9250E-01	4.8738E-01	4.2803E-01	2.8646E-01	3.7111E-04	4.6804E-04	4.0949E-02	-1.3392E-02
6	3.7192E-01	5.2990E-01	2.4889E-01	6.0678E-01	5.3505E-01	2.9402E-01	3.9779E-04	5.0307E-04	2.3766E-02	-1.7351E-02
7	4.5783E-01	6.2049E-01	3.2427E-01	7.2501E-01	6.4208E-01	2.9176E-01	4.3336E-04	5.7944E-04	1.5008E-02	-2.1408E-02
8	5.6090E-01	7.0561E-01	4.1091E-01	8.4281E-01	7.4909E-01	2.9335E-01	4.7600E-04	6.7597E-04	1.8301E-02	-2.7190E-02
9	6.7429E-01	7.8556E-01	5.1354E-01	9.6056E-01	8.5011E-01	2.9609E-01	5.2437E-04	7.9103E-04	3.1201E-02	-3.3030E-02
10	8.0271E-01	8.5941E-01	6.3027E-01	1.0805E+00	9.6312E-01	3.0031E-01	5.7780E-04	9.3294E-04	4.6674E-02	-3.9902E-02
11	9.4583E-01	9.3440E-01	7.6162E-01	1.2026E+00	1.0701E+00	3.0608E-01	6.4256E-04	1.1139E-03	6.0093E-02	-4.6472E-02
12	1.1061E+00	1.0021E+00	9.0627E-01	1.3260E+00	1.1771E+00	3.1251E-01	7.2230E-04	1.2154E-03	7.2507E-02	-4.9015E-02
13	1.2833E+00	1.0021E+00	1.0742E+00	1.4473E+00	1.2642E+00	3.2188E-01	8.3945E-04	1.6830E-03	8.0420E-02	-5.3492E-02
14	1.4800E+00	1.1230E+00	1.2489E+00	1.5908E+00	1.3912E+00	3.3031E-01	1.0138E-03	2.3019E-03	8.4406E-02	-5.5558E-02
15	1.6945E+00	1.1839E+00	1.4444E+00	1.7287E+00	1.4988E+00	3.3933E-01	1.3045E-03	3.0074E-03	8.3340E-02	-5.6409E-02
16	1.9278E+00	1.2452E+00	1.6571E+00	1.8710E+00	1.6052E+00	3.4815E-01	1.7670E-03	4.3961E-03	8.0811E-02	-5.5978E-02
17	2.1794E+00	1.3167E+00	1.8870E+00	2.0175E+00	1.7122E+00	3.5655E-01	2.6171E-03	6.9438E-03	7.5097E-02	-5.6493E-02
18	2.4500E+00	1.3869E+00	2.1062E+00	1.8192E+00	1.8192E+00	3.6634E-01	4.2645E-03	1.1629E-02	6.9536E-02	-5.2198E-02

N= 1

N	X	Y	Z	U	V	W	SR	RHO	MACH	DN
1	2.2000E-01	2.9773E-06	1.2787E-01	2.1652E-06	1.9493E-06	2.5406E-01	1.7521E-04	1.7018E-04	1.4043E-01	0.0
2	2.2457E-01	1.1004E-01	1.2176E-01	1.2044E-01	1.0701E-01	2.5922E-01	3.0481E-04	3.4460E-04	1.0608E-01	-1.6011E-03
3	2.3293E-01	2.2239E-01	1.3157E-01	2.4343E-01	2.1403E-01	2.7280E-01	3.1382E-04	3.6104E-04	1.1851E-01	-2.7942E-03
4	2.6067E-01	3.3185E-01	1.5365E-01	3.6617E-01	3.2104E-01	4.8091E-01	3.4607E-04	4.0849E-04	5.9478E-02	-9.6260E-03
5	3.0422E-01	4.3555E-01	1.9250E-01	4.8738E-01	4.2803E-01	2.8646E-01	3.7111E-04	4.6804E-04	4.0949E-02	-1.3392E-02
6	3.7192E-01	5.2990E-01	2.4889E-01	6.0678E-01	5.3505E-01	2.9402E-01	3.9779E-04	5.0307E-04	2.3766E-02	-1.7351E-02
7	4.5783E-01	6.2049E-01	3.2427E-01	7.2501E-01	6.4208E-01	2.9176E-01	4.3336E-04	5.7944E-04	1.5008E-02	-2.1408E-02
8	5.6090E-01	7.0561E-01	4.1091E-01	8.4281E-01	7.4909E-01	2.9335E-01	4.7600E-04	6.7597E-04	1.8301E-02	-2.7190E-02
9	6.7429E-01	7.8556E-01	5.1354E-01	9.6056E-01	8.5011E-01	2.9609E-01	5.2437E-04	7.9103E-04	3.1201E-02	-3.3030E-02
10	8.0271E-01	8.5941E-01	6.3027E-01	1.0805E+00	9.6312E-01	3.0031E-01	5.7780E-04	9.3294E-04	4.6674E-02	-3.9902E-02
11	9.4583E-01	9.3440E-01	7.6162E-01	1.2026E+00	1.0701E+00	3.0608E-01	6.4256E-04	1.1139E-03	6.0093E-02	-4.6472E-02
12	1.1061E+00	1.0021E+00	9.0627E-01	1.3260E+00	1.1771E+00	3.1251E-01	7.2230E-04	1.2154E-03	7.2507E-02	-4.9015E-02
13	1.2833E+00	1.0021E+00	1.0742E+00	1.4473E+00	1.2642E+00	3.2188E-01	8.3945E-04	1.6830E-03	8.0420E-02	-5.3492E-02
14	1.4800E+00	1.1230E+00	1.2489E+00	1.5908E+00	1.3912E+00	3.3031E-01	1.0138E-03	2.3019E-03	8.4406E-02	-5.5558E-02
15	1.6945E+00	1.1839E+00	1.4444E+00	1.7287E+00	1.4988E+00	3.3933E-01	1.3045E-03	3.0074E-03	8.3340E-02	-5.6409E-02
16	1.9278E+00	1.2452E+00	1.6571E+00	1.8710E+00	1.6052E+00	3.4815E-01	1.7670E-03	4.3961E-03	8.0811E-02	-5.5978E-02
17	2.1794E+00	1.3167E+00	1.8870E+00	2.0175E+00	1.7122E+00	3.5655E-01	2.6171E-03	6.9438E-03	7.5097E-02	-5.6493E-02
18	2.4500E+00	1.3869E+00	2.1062E+00	1.8192E+00	1.8192E+00	3.6634E-01	4.2645E-03	1.1629E-02	6.9536E-02	-5.2198E-02

N= 2

N	X	Y	Z	U	V	W	SR	RHO	MACH	DN
1	2.2000E-01	2.9773E-06	1.2787E-01	2.1652E-06	1.9493E-06	2.5406E-01	1.7521E-04	1.7018E-04	1.4043E-01	0.0
2	2.2457E-01	1.1004E-01	1.2176E-01	1.2044E-01	1.0701E-01	2.5922E-01	3.0481E-04	3.4460E-04	1.0608E-01	-1.6011E-03
3	2.3293E-01	2.2239E-01	1.3157E-01	2.4343E-01	2.1403E-01	2.7280E-01	3.1382E-04	3.6104E-04	1.1851E-01	-2.7942E-03
4	2.6067E-01	3.3185E-01	1.5365E-01	3.6617E-01	3.2104E-01	4.8091E-01	3.4607E-04	4.0849E-04	5.9478E-02	-9.6260E-03
5	3.0422E-01	4.3555E-01	1.9250E-01	4.8738E-01	4.2803E-01	2.8646E-01	3.7111E-04	4.6804E-04	4.0949E-02	-1.3392E-02
6	3.7192E-01	5.2990E-01	2.4889E-01	6.0678E-01	5.3505E-01	2.9402E-01	3.9779E-04	5.0307E-04	2.3766E-02	-1.7351E-02
7	4.5783E-01	6.2049E-01	3.2427E-01	7.2501E-01	6.4208E-01	2.9176E-01	4.3336E-04	5.7944E-04	1.5008E-02	-2.1408E-02
8	5.6090E-01	7.0561E-01	4.1091E-01	8.4281E-01	7.4909E-01	2.9335E-01	4.7600E-04	6.7597E-04	1.8301E-02	-2.7190E-02
9	6.7429E-01	7.8556E-01	5.1354E-01	9.6056E-01	8.5011E-01	2.9609E-01	5.2437E-04	7.9103E-04	3.1201E-02	-3.3030E-02
10	8.0271E-01	8.5941E-01	6.3027E-01	1.0805E+00	9.6312E-01	3.0031E-01	5.7780E-04	9.3294E-04	4.6674E-02	-3.9902E-02
11	9.4583E-01	9.3440E-01	7.6162E-01	1.2026E+00	1.0701E+00	3.0608E-01	6.4256E-04	1.1139E-03	6.0093E-02	-4.6472E-02
12	1.1061E+00	1.0021E+00	9.0627E-01	1.3260E+00	1.1771E+00	3.1251E-01	7.2230E-04	1.2154E-03	7.2507E-02	-4.9015E-02
13	1.2833E+00	1.0021E+00	1.0742E+00	1.4473E+00	1.2642E+00	3.2188E-01	8.3945E-04	1.6830E-03	8.0420E-02	-5.3492E-02
14	1.4800E+00	1.1230E+00	1.2489E+00	1.5908E+00	1.3912E+00	3.3031E-01	1.0138E-03	2.3019E-03	8.4406E-02	-5.5558E-02
15	1.6945E+00	1.1839E+00	1.4444E+00	1.7287E+00	1.4988E+00	3.3933E-01	1.3045E-03	3.0074E-03	8.3340E-02	-5.6409E-02
16	1.9278E+00	1.2452E+00	1.6571E+00	1.8710E+00	1.6052E+00	3.4815E-01	1.7670E-03	4.3961E-03	8.0811E-02	-5.5978E-02
17	2.1794E+00	1.3167E+00	1.8870E+00	2.0175E+00	1.7122E+00	3.5655E-01	2.6171E-03	6.9438E-03	7.5097E-02	-5.6493E-02
18	2.4500E+00	1.3869E+00	2.1062E+00	1.8192E+00	1.8192E+00	3.6634E-01	4.2645E-03	1.1629E-02	6.9536E-02	-5.2198E-02

FIELD OUTPUT (SAMPLE CASE 3).

## TRANSFORMATION FUNCTIONS

PLANE 1 THETA= 0.00

M= 1

M	HI	ETA	AG	REG	IMG	CIS1	CIS2	PHI1	PHI2
1	0.	1.6691E-01	9.7525E-01	-1.6009E-05	-9.7925E-01	-1.4306E-05	1.0000E+00	1.8524E-04	1.0497E+00
2	1.0678E-01	1.6820E-01	9.6889E-01	1.9214E-01	-9.6549E-01	1.0542E-01	9.9443E-01	-1.1933E-01	9.0138E-01
3	2.1356E-01	1.7204E-01	9.5557E-01	1.8711E-01	-9.3708E-01	1.9581E-01	9.8064E-01	2.6014E-02	8.7600E-01
4	3.2034E-01	1.7954E-01	9.4222E-01	2.8575E-01	-9.1861E-01	2.9681E-01	9.5409E-01	4.6643E-02	1.1301E+00
5	4.2712E-01	1.7981E-01	9.5629E-01	4.0840E-01	-8.6670E-01	4.2706E-01	9.0422E-01	-3.0018E-01	1.4255E+00
6	5.3390E-01	1.7102E-01	9.8817E-01	5.0318E-01	-7.5603E-01	5.5405E-01	8.3248E-01	-7.9706E-01	1.0900E+00
7	6.4068E-01	1.4032E-01	8.4432E-01	5.2543E-01	-6.5283E-01	6.3415E-01	7.7321E-01	-6.5058E-01	6.8731E-01
8	7.4746E-01	1.4537E-01	8.0740E-01	5.6160E-01	-5.4078E-01	6.9514E-01	7.1887E-01	-3.9470E-01	7.9203E-01
9	8.5424E-01	1.3189E-01	7.7501E-01	5.7667E-01	-4.9466E-01	7.6962E-01	6.3626E-01	-7.5455E-01	1.0638E+00
10	9.6102E-01	1.1946E-01	7.0900E-01	5.8784E-01	-3.9638E-01	8.2912E-01	5.5948E-01	-9.4757E-01	2.6436E-01
11	1.0678E+00	1.1189E-01	6.5370E-01	5.6171E-01	-3.3437E-01	8.5428E-01	5.1150E-01	-6.4607E-01	4.8334E-01
12	1.1746E+00	9.8595E-02	6.1312E-01	5.6939E-01	-2.7722E-01	8.9605E-01	4.6439E-01	-8.7760E-01	7.2533E-01
13	1.2814E+00	9.0055E-02	5.5335E-01	5.0996E-01	-2.1463E-01	9.2156E-01	3.8623E-01	-9.6445E-01	2.7502E-01
14	1.3881E+00	7.8729E-02	5.0728E-01	4.7385E-01	-1.8111E-01	9.3410E-01	3.5701E-01	-7.6621E-01	2.6134E-01
15	1.4949E+00	6.9955E-02	4.6515E-01	4.3938E-01	-1.5265E-01	9.4601E-01	3.2619E-01	-8.2847E-01	1.0125E-01
16	1.6017E+00	6.5175E-02	4.3046E-01	4.0811E-01	-1.3691E-01	9.4807E-01	3.1805E-01	-8.5651E-01	9.1112E-02
17	1.7085E+00	6.0571E-02	4.0050E-01	3.8110E-01	-1.2313E-01	9.5157E-01	3.0744E-01	-6.5702E-01	1.8285E-02
18	1.8153E+00	5.6572E-02	3.7564E-01	3.5802E-01	-1.1137E-01	9.5308E-01	3.0273E-01	-5.8468E-01	5.1116E-02

M= 2

M	HI	ETA	AG	REG	IMG	CIS1	CIS2	PHI1	PHI2
1	0.	1.8415E-01	9.6195E-01	-1.1046E-05	-9.6195E-01	-1.1525E-05	1.0000E+00	1.3717E-04	1.0150E+00
2	1.0678E-01	1.8715E-01	9.5240E-01	9.8510E-02	-9.4729E-01	1.0343E-01	9.9464E-01	-9.2935E-02	9.0507E-01
3	2.1356E-01	1.9734E-01	9.3507E-01	1.8418E-01	-9.2083E-01	1.9618E-01	9.8058E-01	-7.2337E-03	8.9508E-01
4	3.2034E-01	2.0056E-01	9.3983E-01	2.8023E-01	-8.9708E-01	2.9617E-01	9.5451E-01	2.8070E-02	1.1086E+00
5	4.2712E-01	2.0194E-01	9.2780E-01	3.7602E-01	-8.4156E-01	4.2102E-01	9.0705E-01	-3.0191E-01	1.3119E+00
6	5.3390E-01	1.9569E-01	8.8424E-01	4.7644E-01	-7.4440E-01	5.3642E-01	8.4242E-01	-6.8420E-01	1.0602E+00
7	6.4068E-01	1.8768E-01	8.2777E-01	5.1361E-01	-6.4916E-01	6.2048E-01	7.8422E-01	-6.2487E-01	7.5446E-01
8	7.4746E-01	1.7629E-01	7.8323E-01	5.4018E-01	-5.7416E-01	6.8522E-01	7.2833E-01	-5.7809E-01	7.9296E-01
9	8.5424E-01	1.6634E-01	7.4965E-01	5.6506E-01	-4.9263E-01	7.5376E-01	6.5714E-01	-6.9114E-01	9.0190E-01
10	9.6102E-01	1.5734E-01	6.9957E-01	5.6114E-01	-4.0661E-01	8.0775E-01	5.8677E-01	-8.7402E-01	6.2651E-01
11	1.0678E+00	1.5293E-01	6.4014E-01	5.4073E-01	-3.4204E-01	8.4470E-01	5.3525E-01	-7.0042E-01	5.3052E-01
12	1.1746E+00	1.4066E-01	5.9564E-01	5.2335E-01	-2.8442E-01	9.0763E-01	4.7750E-01	-7.9937E-01	5.7505E-01
13	1.2814E+00	1.3088E-01	5.4475E-01	4.9210E-01	-2.3365E-01	9.3035E-01	4.2091E-01	-8.6217E-01	3.5350E-01
14	1.3881E+00	1.1833E-01	5.0045E-01	4.5470E-01	-1.9780E-01	9.1858E-01	3.9523E-01	-7.7669E-01	2.5778E-01
15	1.4949E+00	1.0737E-01	4.6149E-01	4.2874E-01	-1.7075E-01	9.2903E-01	3.7000E-01	-7.5252E-01	1.6629E-01
16	1.6017E+00	1.0268E-01	4.2791E-01	3.9994E-01	-1.5217E-01	9.3464E-01	3.5559E-01	-8.7138E-01	1.1533E-01
17	1.7085E+00	1.2269E-01	3.9930E-01	3.7479E-01	-1.3777E-01	9.3659E-01	3.4504E-01	-6.2649E-01	7.0027E-02
18	1.8153E+00	1.2103E-01	3.7460E-01	3.5250E-01	-1.2676E-01	9.4101E-01	3.3839E-01	-5.7748E-01	4.6593E-02

M= 3

M	HI	ETA	AG	REG	IMG	CIS1	CIS2	PHI1	PHI2
1	0.	2.0146E-01	9.4545E-01	-8.9210E-06	-9.4545E-01	-9.4557E-06	1.0000E+00	1.0422E-04	9.8076E-01
2	1.0678E-01	2.0610E-01	9.3009E-01	9.5357E-02	-9.3122E-01	1.0187E-01	9.9408E-01	-7.4324E-02	9.1517E-01
3	2.1356E-01	2.1705E-01	9.2248E-01	1.8090E-01	-9.0456E-01	1.9618E-01	9.8058E-01	-9.8762E-03	9.1267E-01
4	3.2034E-01	2.2158E-01	9.1842E-01	2.7387E-01	-8.7663E-01	2.9620E-01	9.5450E-01	-2.2718E-02	1.0845E+00
5	4.2712E-01	2.2607E-01	9.0216E-01	3.7436E-01	-8.2002E-01	4.1496E-01	9.0944E-01	-3.0044E-01	1.2237E+00
6	5.3390E-01	2.2035E-01	8.6157E-01	4.7270E-01	-7.3305E-01	5.2544E-01	8.5083E-01	-6.0130E-01	1.0376E+00
7	6.4068E-01	2.1504E-01	8.1037E-01	4.9218E-01	-6.4379E-01	6.0734E-01	7.9444E-01	-5.9206E-01	7.9445E-01
8	7.4746E-01	2.0722E-01	7.6927E-01	5.1840E-01	-5.6637E-01	6.7388E-01	7.1884E-01	-5.1656E-01	7.8047E-01
9	8.5424E-01	2.0078E-01	7.2782E-01	5.3741E-01	-4.9083E-01	7.3838E-01	6.7436E-01	-6.5274E-01	6.2088E-01
10	9.6102E-01	1.9563E-01	6.7632E-01	5.3543E-01	-4.1319E-01	7.9168E-01	6.1094E-01	-7.5575E-01	6.4509E-01
11	1.0678E+00	1.9397E-01	6.2609E-01	5.1891E-01	-3.5031E-01	8.2862E-01	5.5952E-01	-7.0704E-01	5.4828E-01
12	1.1746E+00	1.8942E-01	5.8118E-01	5.0056E-01	-2.9530E-01	8.5129E-01	5.0811E-01	-7.5412E-01	5.1707E-01
13	1.2814E+00	1.8791E-01	5.3501E-01	4.7367E-01	-2.4874E-01	8.8535E-01	4.6443E-01	-7.8780E-01	3.7927E-01
14	1.3881E+00	1.8492E-01	4.9341E-01	4.4497E-01	-2.1320E-01	9.0101E-01	4.3209E-01	-7.4541E-01	2.7695E-01
15	1.4949E+00	1.8346E-01	4.5671E-01	4.1646E-01	-1.8036E-01	9.1296E-01	4.0405E-01	-7.0050E-01	1.9828E-01
16	1.6017E+00	1.8218E-01	4.2473E-01	3.8947E-01	-1.5222E-01	9.2000E-01	3.7600E-01	-6.5050E-01	1.4110E-01
17	1.7085E+00	1.8480E-01	3.9717E-01	3.6222E-01	-1.2676E-01	9.2550E-01	3.5250E-01	-5.7748E-01	1.0039E-01
18	1.8153E+00	1.8549E-01	3.7322E-01	3.3922E-01	-1.0422E-01	9.3000E+00	3.3000E+00	-5.7748E-01	6.9115E-02

JOUT = 1 (SAMPLE CASE 3).



N	MI	ETA	AC	REG	IMG	CIS1	CIS2	PHI1	PHI2
1	0.	2.1874E-01	9.2961E-01	-7.2762E-06	-9.2961E-01	-7.8297E-06	1.0000E+00	8.0676E-05	9.6620E-01
2	1.0678E-01	2.2505E-01	9.2002E-01	9.2549E-02	-9.1535E-01	1.0039E-01	9.9435E-01	-6.1551E-02	9.1407E-01
3	2.1356E-01	2.3575E-01	9.0594E-01	1.7734E-01	-8.8647E-01	1.9576E-01	9.8065E-01	-2.5204E-02	9.2244E-01
4	3.2034E-01	2.4260E-01	8.9795E-01	2.6700E-01	-8.5734E-01	2.9734E-01	9.5477E-01	-6.1307E-02	1.0598E+00
5	4.2712E-01	2.4621E-01	8.7676E-01	3.5535E-01	-8.0192E-01	4.0893E-01	9.1256E-01	-2.9726E-01	1.1341E+00
6	5.3390E-01	2.4529E-01	8.4012E-01	4.3135E-01	-7.2092E-01	5.1345E-01	8.5612E-01	-5.3622E-01	1.0074E+00
7	6.4048E-01	2.4239E-01	7.9270E-01	4.7145E-01	-6.3726E-01	5.9476E-01	8.0392E-01	-5.6134E-01	8.1546E-01
8	7.4746E-01	2.3915E-01	7.5082E-01	4.9688E-01	-5.6280E-01	6.6170E-01	7.4909E-01	-5.3105E-01	7.8153E-01
9	8.5424E-01	2.3523E-01	7.0819E-01	5.1229E-01	-4.8846E-01	7.2339E-01	6.9044E-01	-5.0243E-01	7.7164E-01
10	9.6102E-01	2.3371E-01	6.5985E-01	5.1105E-01	-4.1743E-01	7.7439E-01	6.3260E-01	-4.7001E-01	6.4021E-01
11	1.0678E+00	2.3501E-01	6.1208E-01	4.9724E-01	-3.5619E-01	8.1240E-01	5.8101E-01	-4.6996E-01	5.5276E-01
12	1.1746E+00	2.3479E-01	5.6607E-01	4.7935E-01	-3.0479E-01	8.4367E-01	5.3654E-01	-4.7168E-01	4.9106E-01
13	1.2814E+00	2.3684E-01	5.2505E-01	4.5547E-01	-2.6120E-01	8.6748E-01	4.9747E-01	-4.7321E-01	4.5870E-01
14	1.3881E+00	2.3802E-01	4.8595E-01	4.2947E-01	-2.2671E-01	8.8451E-01	4.6522E-01	-4.7004E-01	4.2940E-01
15	1.4949E+00	2.4019E-01	4.5127E-01	4.0450E-01	-2.0007E-01	8.9635E-01	4.4344E-01	-4.6422E-01	4.0283E-01
16	1.6017E+00	2.4369E-01	4.2024E-01	3.8058E-01	-1.7961E-01	9.0435E-01	4.2680E-01	-4.6220E-01	3.8077E-01
17	1.7085E+00	2.4651E-01	3.9438E-01	3.5891E-01	-1.6346E-01	9.1006E-01	4.1647E-01	-4.6205E-01	3.6079E-01
18	1.8153E+00	2.4994E-01	3.7127E-01	3.3939E-01	-1.5053E-01	9.1412E-01	4.0545E-01	-4.6204E-01	3.4216E-01

N	MI	ETA	AC	REG	IMG	CIS1	CIS2	PHI1	PHI2
1	0.	2.3601E-01	9.1432E-01	-6.0065E-06	-9.1432E-01	-6.5693E-06	1.0000E+00	6.3895E-05	9.5443E-01
2	1.0678E-01	2.4400E-01	9.0421E-01	9.9980E-02	-8.9972E-01	9.9297E-02	9.9204E-01	-5.3604E-02	9.1419E-01
3	2.1356E-01	2.5645E-01	8.8577E-01	1.7359E-01	-8.7247E-01	1.9514E-01	9.8078E-01	-3.8746E-02	8.7688E-01
4	3.2034E-01	2.6322E-01	8.6739E-01	2.5983E-01	-8.3909E-01	2.9580E-01	9.5525E-01	-9.0535E-02	1.0334E+00
5	4.2712E-01	2.6834E-01	8.5715E-01	3.4540E-01	-7.9448E-01	4.0296E-01	9.1522E-01	-4.9317E-01	1.0977E+00
6	5.3390E-01	2.6968E-01	8.4197E-01	4.1195E-01	-7.0878E-01	5.0258E-01	8.6458E-01	-4.9279E-01	9.7855E-01
7	6.4048E-01	2.6975E-01	8.1797E-01	4.5161E-01	-6.2949E-01	5.8264E-01	8.1233E-01	-5.3316E-01	8.2559E-01
8	7.4746E-01	2.6907E-01	7.7329E-01	4.7597E-01	-5.5741E-01	6.4537E-01	7.6048E-01	-5.2135E-01	7.7298E-01
9	8.5424E-01	2.6967E-01	7.2904E-01	4.8901E-01	-4.8685E-01	7.0867E-01	7.0554E-01	-6.0019E-01	7.3786E-01
10	9.6102E-01	2.7179E-01	6.4390E-01	4.8800E-01	-4.2008E-01	7.5788E-01	6.5239E-01	-6.5397E-01	6.3064E-01
11	1.0678E+00	2.7405E-01	5.9837E-01	4.7021E-01	-3.6322E-01	7.9586E-01	6.0531E-01	-6.6605E-01	5.5090E-01
12	1.1746E+00	2.8015E-01	5.5571E-01	4.5924E-01	-3.1408E-01	8.2644E-01	5.6303E-01	-6.8189E-01	4.7932E-01
13	1.2814E+00	2.8577E-01	5.1514E-01	4.3772E-01	-2.7101E-01	8.4970E-01	5.2725E-01	-6.8731E-01	4.0868E-01
14	1.3881E+00	2.9111E-01	4.7827E-01	4.1459E-01	-2.3837E-01	8.6537E-01	4.9844E-01	-6.8733E-01	3.5908E-01
15	1.4949E+00	2.9692E-01	4.4534E-01	3.9162E-01	-2.1208E-01	8.7934E-01	4.7020E-01	-6.8351E-01	3.0858E-01
16	1.6017E+00	3.0319E-01	4.1640E-01	3.6985E-01	-1.9130E-01	8.8622E-01	4.5942E-01	-6.8013E-01	2.6164E-01
17	1.7085E+00	3.0903E-01	3.9104E-01	3.4990E-01	-1.7461E-01	8.9478E-01	4.4631E-01	-6.6022E-01	2.1474E-01
18	1.8153E+00	3.1440E-01	3.6879E-01	3.3178E-01	-1.6103E-01	8.9966E-01	4.3603E-01	-6.5202E-01	1.7465E-01

N	MI	ETA	AC	REG	IMG	CIS1	CIS2	PHI1	PHI2
1	0.	2.5729E-01	8.9951E-01	-5.0054E-06	-8.9951E-01	-5.5046E-06	1.0000E+00	5.1253E-05	9.7930E-01
2	1.0678E-01	2.6295E-01	8.8870E-01	8.7601E-02	-8.8437E-01	9.8573E-02	9.9513E-01	-4.7742E-02	9.1413E-01
3	2.1356E-01	2.7616E-01	8.7347E-01	1.6969E-01	-8.5653E-01	1.9427E-01	9.8095E-01	-3.0564E-02	8.7616E-01
4	3.2034E-01	2.8464E-01	8.5970E-01	2.5254E-01	-8.2177E-01	2.9375E-01	9.5508E-01	-1.1200E-01	1.0118E+00
5	4.2712E-01	2.9047E-01	8.3709E-01	3.3235E-01	-7.6021E-01	3.9704E-01	9.1779E-01	-2.8959E-01	1.0312E+00
6	5.3390E-01	2.9434E-01	8.0052E-01	3.9414E-01	-6.9676E-01	4.9236E-01	8.7039E-01	-4.5066E-01	9.5151E-01
7	6.4048E-01	2.9711E-01	7.5784E-01	4.3274E-01	-6.2213E-01	5.7702E-01	8.2094E-01	-5.0754E-01	8.2315E-01
8	7.4746E-01	3.0000E-01	7.1577E-01	4.5585E-01	-5.5184E-01	6.7066E-01	7.7098E-01	-5.2341E-01	7.6313E-01
9	8.5424E-01	3.0612E-01	6.7302E-01	4.6722E-01	-4.8442E-01	6.9421E-01	7.1977E-01	-5.7789E-01	7.1384E-01
10	9.6102E-01	3.0987E-01	6.2455E-01	4.6623E-01	-4.2156E-01	7.4145E-01	6.7068E-01	-6.2360E-01	6.2613E-01
11	1.0678E+00	3.1709E-01	5.8505E-01	4.5596E-01	-3.6659E-01	7.7935E-01	6.2659E-01	-6.3837E-01	5.4583E-01
12	1.1746E+00	3.2551E-01	5.4365E-01	4.4002E-01	-3.1963E-01	8.0907E-01	5.8771E-01	-6.4683E-01	4.7160E-01
13	1.2814E+00	3.3470E-01	5.0536E-01	4.2047E-01	-2.8034E-01	8.3203E-01	5.5473E-01	-6.4680E-01	3.9250E-01
14	1.3881E+00	3.4421E-01	4.7033E-01	3.9942E-01	-2.4634E-01	8.4923E-01	5.2602E-01	-6.4132E-01	3.1074E-01
15	1.4949E+00	3.5365E-01	4.3910E-01	3.7851E-01	-2.2254E-01	8.6204E-01	5.0688E-01	-6.0369E-01	2.5688E-01
16	1.6017E+00	3.6269E-01	4.1152E-01	3.5872E-01	-2.0106E-01	8.7170E-01	4.9004E-01	-5.7133E-01	2.0669E-01
17	1.7085E+00	3.7114E-01	3.8724E-01	3.4040E-01	-1.8463E-01	8.7903E-01	4.7077E-01	-5.3608E-01	1.6048E-01
18	1.8153E+00	3.7806E-01	3.6584E-01	3.2365E-01	-1.7057E-01	8.8467E-01	4.6023E-01	-5.0525E-01	1.3410E-01

0. (cont'd). FIELD OUTPUT, JOUT = 1 (SAMPLE CASE 3).

LANE 2 IMETA = 24.50

1 MI ETA AC REG IMG CIS1 CIS2 PHI1 PHI2



## CIRCUMFERENTIAL TRANSFORMATION FUNCTIONS

PLANE 1 INFIA= 0.00

N= 1		XI		ETA		REZETPHI		IMZETPHI		REGPHI		INGPHI	
M	1	0.		1.6691E-01		0.		0.		0.		0.	
2	1.06478E-01			1.6820E-01		0.		0.		0.		0.	
3	2.13356E-01			1.7764E-01		0.		0.		0.		0.	
4	3.2034E-01			1.7954E-01		0.		0.		0.		0.	
5	4.2712E-01			1.7981E-01		0.		0.		0.		0.	
6	5.3390E-01			1.7102E-01		0.		0.		0.		0.	
7	6.4068E-01			1.6032E-01		0.		0.		0.		0.	
8	7.4746E-01			1.4537E-01		0.		0.		0.		0.	
9	8.5424E-01			1.3185E-01		0.		0.		0.		0.	
10	9.6102E-01			1.1946E-01		0.		0.		0.		0.	
11	1.0678E+00			1.1189E-01		0.		0.		0.		0.	
12	1.1746E+00			9.8695E-02		0.		0.		0.		0.	
13	1.2814E+00			9.0055E-02		0.		0.		0.		0.	
14	1.3881E+00			7.8729E-02		0.		0.		0.		0.	
15	1.4949E+00			6.9995E-02		0.		0.		0.		0.	
16	1.6017E+00			6.5175E-02		0.		0.		0.		0.	
17	1.7085E+00			6.0571E-02		0.		0.		0.		0.	
18	1.8153E+00			5.6572E-02		0.		0.		0.		0.	

N= 2		XI		ETA		REZETPHI		IMZETPHI		REGPHI		INGPHI	
M	1	0.		1.8419E-01		0.		0.		0.		0.	
2	1.06478E-01			1.8715E-01		0.		0.		0.		0.	
3	2.13356E-01			1.9734E-01		0.		0.		0.		0.	
4	3.2034E-01			2.0056E-01		0.		0.		0.		0.	
5	4.2712E-01			2.0194E-01		0.		0.		0.		0.	
6	5.3390E-01			1.9569E-01		0.		0.		0.		0.	
7	6.4068E-01			1.8768E-01		0.		0.		0.		0.	
8	7.4746E-01			1.7629E-01		0.		0.		0.		0.	
9	8.5424E-01			1.6634E-01		0.		0.		0.		0.	
10	9.6102E-01			1.5754E-01		0.		0.		0.		0.	
11	1.0678E+00			1.5293E-01		0.		0.		0.		0.	
12	1.1746E+00			1.4406E-01		0.		0.		0.		0.	
13	1.2814E+00			1.3898E-01		0.		0.		0.		0.	
14	1.3881E+00			1.3183E-01		0.		0.		0.		0.	
15	1.4949E+00			1.2673E-01		0.		0.		0.		0.	
16	1.6017E+00			1.2468E-01		0.		0.		0.		0.	
17	1.7085E+00			1.2269E-01		0.		0.		0.		0.	
18	1.8153E+00			1.2103E-01		0.		0.		0.		0.	

N= 3		XI		ETA		REZETPHI		IMZETPHI		REGPHI		INGPHI	
M	1	0.		2.0146E-01		0.		0.		0.		0.	
2	1.06478E-01			2.0619E-01		0.		0.		0.		0.	
3	2.13356E-01			2.1705E-01		0.		0.		0.		0.	
4	3.2034E-01			2.2158E-01		0.		0.		0.		0.	
5	4.2712E-01			2.2497E-01		0.		0.		0.		0.	
6	5.3390E-01			2.2035E-01		0.		0.		0.		0.	
7	6.4068E-01			2.1504E-01		0.		0.		0.		0.	
8	7.4746E-01			2.0722E-01		0.		0.		0.		0.	
9	8.5424E-01			2.0078E-01		0.		0.		0.		0.	
10	9.6102E-01			1.9563E-01		0.		0.		0.		0.	
11	1.0678E+00			1.9397E-01		0.		0.		0.		0.	
12	1.1746E+00			1.8942E-01		0.		0.		0.		0.	
13	1.2814E+00			1.8791E-01		0.		0.		0.		0.	
14	1.3881E+00			1.8492E-01		0.		0.		0.		0.	
15	1.4949E+00			1.8146E-01		0.		0.		0.		0.	
16	1.6017E+00			1.8418E-01		0.		0.		0.		0.	
17	1.7085E+00			1.8480E-01		0.		0.		0.		0.	
18	1.8153E+00			1.8549E-01		0.		0.		0.		0.	

p.) FIELD OUTPUT, JOUT = 2 (SAMPLE CASE 3).

N= 4		XI		ETA	REZETPHI	IMZETPHI	RECPhi	INGPhi
1	0.			2.1874F-01	0.	0.	0.	0.
2	1.0678E-01			2.2505F-01	0.	0.	0.	0.
3	2.1356E-01			2.4675F-01	0.	0.	0.	0.
4	3.2034E-01			2.4760F-01	0.	0.	0.	0.
5	4.2712E-01			2.4621F-01	0.	0.	0.	0.
6	5.3390E-01			2.4502E-01	0.	0.	0.	0.
7	6.4068E-01			2.4239F-01	0.	0.	0.	0.
8	7.4746E-01			2.3815E-01	0.	0.	0.	0.
9	8.5424E-01			2.3371E-01	0.	0.	0.	0.
10	9.6102E-01			2.3301F-01	0.	0.	0.	0.
11	1.0678E+00			2.3479F-01	0.	0.	0.	0.
12	1.1746E+00			2.3685E-01	0.	0.	0.	0.
13	1.2814E+00			2.3802E-01	0.	0.	0.	0.
14	1.3881E+00			2.4019F-01	0.	0.	0.	0.
15	1.4949E+00			2.4369F-01	0.	0.	0.	0.
16	1.6017E+00			2.4791F-01	0.	0.	0.	0.
17	1.7085E+00			2.4994F-01	0.	0.	0.	0.
18	1.8153E+00				0.	0.	0.	0.

N= 5		XI		ETA	REZETPHI	IMZETPHI	RECPhi	INGPhi
1	0.			2.3601F-01	0.	0.	0.	0.
2	1.0678E-01			2.4408F-01	0.	0.	0.	0.
3	2.1356E-01			2.5645F-01	0.	0.	0.	0.
4	3.2034E-01			2.6362E-01	0.	0.	0.	0.
5	4.2712E-01			2.6836E-01	0.	0.	0.	0.
6	5.3390E-01			2.6968F-01	0.	0.	0.	0.
7	6.4068E-01			2.6975F-01	0.	0.	0.	0.
8	7.4746E-01			2.6907F-01	0.	0.	0.	0.
9	8.5424E-01			2.6967F-01	0.	0.	0.	0.
10	9.6102E-01			2.7179F-01	0.	0.	0.	0.
11	1.0678E+00			2.7405F-01	0.	0.	0.	0.
12	1.1746E+00			2.8015E-01	0.	0.	0.	0.
13	1.2814E+00			2.8577F-01	0.	0.	0.	0.
14	1.3881E+00			2.9111F-01	0.	0.	0.	0.
15	1.4949E+00			2.9692F-01	0.	0.	0.	0.
16	1.6017E+00			3.0319F-01	0.	0.	0.	0.
17	1.7085E+00			3.0935F-01	0.	0.	0.	0.
18	1.8153E+00			3.1440F-01	0.	0.	0.	0.

N= 6		XI		ETA	REZETPHI	IMZETPHI	RECPhi	INGPhi
1	0.			2.5329F-01	0.	0.	0.	0.
2	1.0678E-01			2.6295E-01	0.	0.	0.	0.
3	2.1356E-01			2.7610F-01	0.	0.	0.	0.
4	3.2034E-01			2.8664F-01	0.	0.	0.	0.
5	4.2712E-01			2.9047F-01	0.	0.	0.	0.
6	5.3390E-01			2.9234F-01	0.	0.	0.	0.
7	6.4068E-01			2.9711F-01	0.	0.	0.	0.
8	7.4746E-01			3.0008F-01	0.	0.	0.	0.
9	8.5424E-01			3.0612F-01	0.	0.	0.	0.
10	9.6102E-01			3.0987F-01	0.	0.	0.	0.
11	1.0678E+00			3.1709F-01	0.	0.	0.	0.
12	1.1746E+00			3.2521F-01	0.	0.	0.	0.
13	1.2814E+00			3.3470F-01	0.	0.	0.	0.
14	1.3881E+00			3.421E-01	0.	0.	0.	0.
15	1.4949E+00			3.5365F-01	0.	0.	0.	0.
16	1.6017E+00			3.6264F-01	0.	0.	0.	0.
17	1.7085E+00			3.7114E-01	0.	0.	0.	0.
18	1.8153E+00			3.7806F-01	0.	0.	0.	0.

ILANE 2 IMETA= 22.50

U= 1  
M XI ETA

p.(cont'd.) FIELD OUTPUT, JOUT = 2 (SAMPLE CASE 3).

REZETPHI IMZETPHI RECPhi INGPhi



7	0.64208E+01	2.5777E+01	-5.0111E-02	1.75114E-02	-5.5403E-04	4.7533E-02
8	7.4909E-01	2.3271E-01	-4.1318E-02	1.02200E-02	-4.2506E-02	5.6422E-02
9	0.5611E-01	2.2809E-01	-4.9108E-02	1.0534E-02	-4.7209E-02	1.8305E-02
10	4.06312E-01	2.2474E-01	-5.5111E-02	7.3294E-03	-4.0667E-02	4.0109E-03
11	1.0701E+00	2.2689E-01	-6.02739E-02	3.5999E-02	-5.2289E-02	-5.0796E-03
12	1.1771E+00	2.2447E-01	-6.4274E-02	-2.7017E-04	-2.2717E-02	-5.6522E-03
13	1.2842E+00	2.2701E-01	-6.6018E-02	-3.6075E-03	-1.0784E-02	-5.5513E-03
14	1.3912E+00	2.2937E-01	-6.6346E-02	-5.7131E-03	-2.0579E-03	-4.8146E-03
15	1.4982E+00	2.3175E-01	-6.6847E-02	-5.9461E-03	-2.7447E-03	-2.0534E-03
16	1.6052E+00	2.3405E-01	-6.5939E-02	-4.4814E-03	-2.7250E-03	-7.9967E-04
17	1.7122E+00	2.3700E-01	-6.6114E-02	-1.7027E-03	-1.7942E-03	-1.2071E-02
18	1.8192E+00	2.4093E-01	-6.7426E-02	1.7642E-03	-5.4099E-04	1.4460E-02

XI						
1	0.	2.3648E-01	REZETPMI	IMZETPMI	RLGPMI	IMGPMI
2	1.0701E-01	2.6167E-01	5.3524E-08	5.5174E-03	5.3458E-07	2.3246E-02
3	2.1403E-01	2.5404E-01	-5.0139E-03	4.1594E-03	5.6136E-03	2.9278E-02
4	3.2104E-01	2.6071E-01	-7.1804E-02	5.7368E-03	1.0308E-02	4.1453E-02
5	4.2805E-01	2.6872E-01	-1.2681E-02	7.7600E-03	1.2665E-02	5.2461E-02
6	5.3507E-01	2.6544E-01	-1.9323E-02	9.3760E-03	-1.4296E-02	5.4551E-02
7	6.4208E-01	2.6476E-01	-2.6411E-02	1.0413E-02	-2.5765E-02	4.7705E-02
8	7.4909E-01	2.6307E-01	-3.3575E-02	1.0457E-02	-3.2204E-02	4.0708E-02
9	8.5611E-01	2.6249E-01	-4.0978E-02	1.0049E-02	-3.9271E-02	5.2404E-02
10	9.6312E-01	2.6353E-01	-4.8425E-02	8.3567E-03	-4.2377E-02	1.8960E-02
11	1.0701E+00	2.6648E-01	-5.6420E-02	5.6040E-03	-5.7034E-02	0.7207E-03
12	1.1771E+00	2.6986E-01	-5.9301E-02	2.0608E-03	-3.0037E-02	-8.0334E-04
13	1.2842E+00	2.7454E-01	-6.2853E-02	-1.3039E-03	-2.1022E-02	-5.3242E-03
14	1.3912E+00	2.7984E-01	-6.6804E-02	-4.1611E-03	-1.1714E-02	-5.5103E-03
15	1.4982E+00	2.8554E-01	-6.5783E-02	-5.7987E-03	-4.4509E-03	-1.9593E-03
16	1.6052E+00	2.9150E-01	-6.6247E-02	-5.9434E-03	-5.7321E-04	3.2394E-03
17	1.7122E+00	2.9722E-01	-6.6666E-02	-4.6732E-03	-3.8785E-04	7.9745E-03
18	1.8192E+00	3.0264E-01	-6.8004E-02	-2.3102E-03	-2.6132E-04	1.1425E-02

XI						
1	1.9493E-00	2.5400E-01	REZETPMI	IMZETPMI	RLGPMI	IMGPMI
2	1.0701E-01	2.5972E-01	2.4284E-04	3.0559E-03	8.6005E-06	2.5009E-02
3	2.1403E-01	2.7280E-01	-5.2628E-03	3.5685E-03	8.0077E-07	5.0031E-02
4	3.2104E-01	2.8091E-01	-7.5639E-03	4.9089E-03	8.1768E-03	4.0081E-02
5	4.2805E-01	2.8644E-01	-1.3064E-02	6.6329E-03	-1.5006E-04	5.0094E-02
6	5.3507E-01	2.8982E-01	-1.9573E-02	7.9709E-03	-1.3641E-02	5.1047E-02
7	6.4208E-01	2.9176E-01	-2.6503E-02	8.5930E-03	-2.4048E-02	4.5910E-02
8	7.4909E-01	2.9343E-01	-3.3522E-02	8.6417E-03	-3.0527E-02	3.9140E-02
9	8.5611E-01	2.9609E-01	-4.0644E-02	7.9982E-03	-3.6262E-02	3.0089E-02
10	9.6312E-01	3.0031E-01	-4.7155E-02	6.2843E-03	-3.8329E-02	1.9389E-02
11	1.0701E+00	3.0508E-01	-5.3464E-02	3.6297E-03	-3.4555E-02	0.8585E-03
12	1.1771E+00	3.1325E-01	-5.8193E-02	5.6949E-04	-2.7935E-02	1.8405E-03
13	1.2842E+00	3.2148E-01	-6.1648E-02	-2.4249E-03	-2.0100E-02	-1.8741E-03
14	1.3912E+00	3.3031E-01	-6.3908E-02	-4.8376E-03	-1.2209E-02	-2.0113E-03
15	1.4982E+00	3.3933E-01	-6.5320E-02	-6.1937E-03	-6.9419E-03	5.6120E-04
16	1.6052E+00	3.4815E-01	-6.6412E-02	-6.2742E-03	-2.7147E-03	4.5129E-03
17	1.7122E+00	3.5655E-01	-6.7671E-02	-5.1622E-03	-1.5198E-03	0.2648E-03
18	1.8192E+00	3.6434E-01	-6.9351E-02	-3.1000E-03	-1.4474E-03	1.1125E-02

PLANE 7 IMETA= 45.00

XI						
1	0.	1.7074E-01	REZETPMI	IMZETPMI	RLGPMI	IMGPMI
2	1.0701E-01	1.7170E-01	2.1263E-07	7.5605E-03	5.4601E-06	1.9540E-02
3	2.1403E-01	1.7970E-01	-2.4059E-03	9.5046E-03	2.9134E-02	5.5003E-02
4	3.2104E-01	1.8001E-01	-7.7311E-03	1.4074E-02	3.6393E-02	6.6457E-02
5	4.2805E-01	1.7311E-01	-1.6057E-02	2.0197E-02	2.1009E-02	1.0251E-01
6	5.3507E-01	1.6018E-01	-2.7458E-02	2.6314E-02	-2.9009E-02	1.2200E-01
7	6.4208E-01	1.4770E-01	-4.1837E-02	2.9493E-02	-6.6837E-02	0.7005E-01
8	7.4909E-01	1.3314E-01	-5.4669E-02	3.0721E-02	-6.5090E-02	7.0265E-02
9	8.5611E-01	1.1771E-01	-6.8702E-02	5.2087E-02	-8.7109E-02	6.8173E-02

P. (cont'd.) FIELD OUTPUT, JOUT = 2 (SAMPLE CASE 3).

DISTRIBUTION LIST

Ballistic Missile Office  
BMO/SYDT  
Attn: Maj. K. Yelmgren  
Norton AFB, CA 92409

TRW DSSG (2)  
Attn: D. Farlow  
T. Lin  
P. O. Box 1310  
San Bernardino, CA 92402

TRW Systems Group  
Attn: M. Gyetvay  
1 Space Park  
Redondo Beach, CA 92078

Defense Technical Information Center (2)  
Cameron Station  
Alexandria, VA 22314